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The M_L Scale in Norway

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A new local magnitude M_L scale has been developed for Norway, based on a regression analysis of synthesized Wood-Anderson records. The scale is applicable for distances up to more than 1000 km, and the data used comprise 741 short-period recordings at 21 seismic stations from 195 earthquakes in the magnitude range 1 to 5 occurring in and around Norway over the last 20 years. Magnitude corrections for distance have been evaluated in terms of a geometrical spreading term a and an anelastic attenuation term b, and the significant regional crustal differences in the area under investigation made it desirable to develop these for several subsets of the data base. The results for a a generally found to be around the commonly found value of 1.0 (using the L_g phase), while the b-values are found to be around 0.0008, consistent with the weak, intraplate attenuation expected for Norway. Compared to interplate California, this difference in attenuation represents more than one magnitude unit at a distance of 1000 km.

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$$M_L = log A_{wa} + a \ log(R/60) + b \ (R - 60) + 2.68 + S$$

where A_{wa} is synthesized Wood-Anderson amplitude (in mm), R is hypocentral distance (in km), and S is a station correction term that for all 21 stations is found to lie within the range $\pm$ 0.22. When using the entire data base the spreading term a equals 1.02, and the anelastic attenuation term b equals 0.00080. When only strictly continental ray paths are selected, the a-value decreases to 0.91 while the b-value increases to 0.00087, a difference which on the average accounts for less than 0.1 magnitude units. While all values used in the regressions have been derived for vertical amplitudes, a separate analysis has shown that these are not significantly different from the horizontal ones, and the new scale is therefore applicable to both. In order to facilitate the practical use of this new M_L scale, a relation has also been established between observed seismogram amplitudes (corrected for instrument response) and the synthesized Wood-Anderson amplitudes. This relation reads $log A_{wa} = 0.925 \ log A_{obs} - 2.32$.

The new M_L magnitudes for the events analyzed are in fairly good agreement with those calculated from a previously used relation developed by Båth for Sweden. The new values are, however, systematically about 0.4 magnitude units lower, which is mostly due to the combined effect of a reference distance less than 100 km and a Wood-Anderson magnification of 2080 instead of the earlier value of 2800. The new M_L values have also regressively been related to a data set of M_S values, yielding the relation $M_S = 0.83 M_L + 1.09$.

Preface

Under Contract No. F49620-C-89-0038, NTNF/NORSAR is conducting research within a wide range of subjects relevant to seismic monitoring. The emphasis of the research program is on developing and assessing methods for processing of data recorded by networks of small-aperture arrays and 3-component stations, for events both at regional and teleseismic distances. In addition, more general seismological research topics are addressed.

Each quarterly technical report under this contract presents one or several separate investigations addressing specific problems within the scope of the statement of work. Summaries of the research efforts within the program as a whole are given in annual technical reports.

This Scientific Report No. 5 presents a manuscript entitled "The ML scale in Norway", by *A. Alsaker, L.B. Kvamme, R.A. Hansen, A. Dahle, and H. Bungum.*

THE M_L SCALE IN NORWAY

by

A. ALSAKER, L.B. KVAMME, R.A. HANSEN, A. DAHLE, AND H. BUNGUM

ABSTRACT

A new local magnitude M_L scale has been developed for Norway, based on a regression analysis of synthesized Wood-Anderson records. The scale is applicable for distances up to more than 1000 km, and the data used comprise 741 short-period recordings at 21 seismic stations from 195 earthquakes in the magnitude range 1 to 5 occurring in and around Norway over the last 20 years. Magnitude corrections for distance have been evaluated in terms of a geometrical spreading term a and an anelastic attenuation term b, and the significant regional crustal differences in the area under investigation made it desirable to develop these for several subsets of the data base. The results for a are generally found to be around the commonly found value of 1.0 (using the L_g phase), while the b-values are found to be around 0.0008, consistent with the weak, intraplate attenuation expected for Norway. Compared to interplate California, this difference in attenuation represents more than one magnitude unit at a distance of 1000 km.

New M_L scales are commonly tied to Richter's original definition at the standard reference hypocentral distance of 100 km. The significantly weaker L_g wave attenuation in Norway, however, requires a smaller reference distance. We have chosen a value of 60 km, based on an overall assessment of regional coverage, focal depths and quality of the data. The resulting M_L formula for Norway reads

$$M_L = logA_{wa} + a\ log(R/60) + b\ (R - 60) + 2.68 + S$$

where A_{wa} is synthesized Wood-Anderson amplitude (in mm), R is hypocentral distance (in km), and S is a station correction term that for all 21 stations is found to lie within the range $\pm$ 0.22. When using the entire data base the spreading term a equals 1.02, and the anelastic attenuation term b equals 0.00080. When only strictly continental ray paths are selected, the a-value decreases to 0.91 while the b-value increases to 0.00087, a difference which on the average accounts for less than 0.1 magnitude units. While all values used in the regressions have been derived for vertical amplitudes, a separate analysis has shown that these are not significantly different from the horizontal ones, and the new scale is therefore applicable to both. In order to facilitate the practical use of this new M_L scale, a relation has also been established between observed seismogram amplitudes (corrected for instrument response) and the synthesized Wood-Anderson amplitudes. This relation reads $logA_{wa} = 0.925\ logA_{obs} - 2.32$.

The new M_L magnitudes for the events analyzed are in fairly good agreement with those calculated from a previously used relation developed by Båth for Sweden. The new values are, however, systematically about 0.4 magnitude units lower, which

is mostly due to the combined effect of a reference distance less than 100 km and a Wood-Anderson magnification of 2080 instead of the earlier value of 2800. The new M_L values have also regressively been related to a data set of M_S values, yielding the relation $M_S = 0.83M_L + 1.09$.

INTRODUCTION

The emergence in everyday seismological practice of concepts such as seismic moment, which relates in a well-defined way to energy release, or the "size" of earthquakes, has not reduced the importance of the magnitude concept as developed originally by Richter (1935). A large number of magnitude scales have been developed since then (e.g. Båth, 1981), and most of them are similar to Richter's scale in the sense that they are based on the logarithm of some amplitude measurement. Most of them are also not related in any well-defined way to the energy release. What is important then is consistency, in time as well as in space. For magnitudes such as m_b and M_S, the spatial consistency is taken care of through the use of globally adopted formulas, based on the fact that the attenuation of teleseismic P-waves and 20 sec period S-waves are only moderately affected by local geological conditions. Local conditions show up in these cases only through the possible use of station corrections.

For the local magnitude M_L, based on maximum L_g amplitudes at local and regional distances, a similar use of common distance (attenuation) correction terms would distort rather than secure this consistency. The reason is that the wave attenuation in this case is more dependent upon local geological conditions, especially those relating to different tectonic regimes (in particular transitions between plate margin and intraplate areas). In order for M_L magnitudes to be consistent, the seismic wave attenuation within each region must be determined, and the magnitude relations for the different regions tied together at a near-source reference distance. In addition, local site conditions leading to amplification or deamplification of the measured ground motions are commonly accounted for in terms of station corrections.

For regional distances, the M_L scale is most important simply because it provides the best consistency, stability and measurability. The importance of regional seismology has moreover increased steadily in recent years, as related to societal needs connected to nuclear explosion monitoring, emergency and disaster prevention, building codes, engineering design criteria, insurance, and safety aspects in general.

In Norway, M_L magnitudes were not routinely reported until Båth *et al.* (1976) developed a new local magnitude scale (hereafter for simplicity called Båth's M_L scale) based on Swedish data. The scale was based on Richter's definition with a reference distance of 100 km, and with the analog data used in the development it was found necessary to introduce frequency dependent correction factors. When applying Båth's M_L formula to digitally recorded data it soon became evident that these correction factors were inadequate, but we nevertheless continued to use this scale in Norway in order to maintain consistency until more appropriate and reliable correction terms could be developed.

The purpose of the present paper is to develop such correction terms, and thereby contribute to the establishing of a new M_L scale for Norway. Since the NORSAR array was installed in Norway around 1970, the amount of reliable digital earthquake recordings has increased steadily, not only due to the time factor itself but also because the number of seismic stations is increasing. This development is best illustrated by the fact that data from 21 seismic stations located in Norway have been used in the present study.

METHOD OF ANALYSIS

In following Richter (1935; 1958), the local magnitude M_L is defined as

$$M_L = logA - logA_0 + S \tag{1}$$

where A is measured amplitude (zero-to-peak) in mm on a horizontal component Wood-Anderson seismometer recording, S is a station correction term, and $-logA_0$ is a distance correction term given as

$$-logA_0 = a\ log(R/100) + b(R - 100) + 3.0 \tag{2}$$

where a and b are coefficients for geometrical spreading and anelastic attenuation, respectively, and R is hypocentral distance.

With no station correction, equations (1) and (2) imply that an earthquake which is observed with an amplitude A of 1 mm at a distance of 100 km in Southern California is given a magnitude M_L of 3.0. In developing the first set of A_0 values, from a small data base of Wood-Anderson seismometer recordings from southern California, Richter (1935) did not separate the two attenuation terms as in equation (2). Recently, from very large data bases, Bakun and Joyner (1984) and Hutton and Boore (1987) have developed new attenuation terms for central and southern California, respectively, in surprisingly good agreement with Richter's values. The only exception here is for near-source distances, where Richter's coverage was poorer, especially in terms of focal depths. Because of this, we will replace Richter's attenuation values with those of Hutton and Boore (1987).

In a more general form, equation (2) reads

$$-logA_0 = a \cdot log(R/R_{ref}) + b \cdot (R - R_{ref}) + K(R_{ref}) \tag{3}$$

where R_{ref} is a reference distance that could be different from 100 km, and $K(R_{ref})$ is a constant to be defined below.

To establish the new magnitude scale, we combine equations (1) and (3) to give

$$logA_{ij} = -a\ log(R_{ij}/R_{ref}) - b(R_{ij} - R_{ref}) - \sum_{k=1}^{N_e} M_k\delta_{ik} + \sum_{l=1}^{N_s} S_l\delta_{lj} - K(R_{ref}) \tag{4}$$

where A_{ij} is the amplitude of earthquake i at station j, R_{ij} is hypocentral distance for earthquake i at station j, δ_{ij} is the Kronecker delta (1 if i equals j, otherwise 0), N_s is number of stations, and N_e is number of events.

The parameters to be determined regressively are a, b, M_k and S_l, representing the geometrical spreading, anelastic attenuation, magnitude, and station correction respectively. Equation (4) can be rewritten in matrix form as:

$$\begin{pmatrix} 1 & 0 & 0 & \dots & 0 & 1 & 0 & 0 & \dots & 0 & r_{11} & u_{11} \\ 1 & 0 & 0 & \dots & 0 & 0 & 1 & 0 & \dots & 0 & r_{12} & u_{12} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 1 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & \dots & 1 & r_{1N_s} & u_{1N_s} \\ 0 & 1 & 0 & \dots & 0 & 1 & 0 & 0 & \dots & 0 & r_{21} & u_{21} \\ 0 & 1 & 0 & \dots & 0 & 0 & 1 & 0 & \dots & 0 & r_{22} & u_{22} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & 1 & 0 & 0 & 0 & \dots & 1 & r_{N_eN_s} & u_{N_eN_s} \end{pmatrix} \cdot \begin{pmatrix} M_1 \\ \vdots \\ M_{N_e} \\ S_1 \\ \vdots \\ S_{N_s} \\ -a \\ -b \end{pmatrix} = \begin{pmatrix} y_{11} \\ y_{12} \\ \vdots \\ y_{1N_s} \\ y_{21} \\ y_{22} \\ \vdots \\ y_{N_eN_s} \end{pmatrix} \qquad (5)$$

or $\mathbf{Ax} = \mathbf{y}$ which is a system of at least $N_e + N_s + 2$ linearly independent equations. In equation (5) $r_{ij} = log(R_{ij}/R_{ref})$, $u_{ij} = (R_{ij} - R_{ref})$, and $y_{ij} = logA_{ij} + K(R_{ref})$.

The vector of unknowns ($\mathbf{x}$) can be found by inversion of $\mathbf{A}$, under the constraint that the station corrections sum to zero ($\sum_{k=1}^{N_s} S_k = 0$). The regression coefficients a (geometrical spreading) and b (anelastic attenuation) determine the form of the $-logA_0$ curve in accordance with equation (3). The connection to Richter's M_L definition is achieved as explained above by anchoring our $-logA_0$ values to those of Hutton and Boore (1987), resulting in the following relation

$$K(R_{ref}) = 1.110\ log(R_{ref}/100) + 0.00189(R_{ref} - 100) + 3.0 \qquad (6)$$

which is seen to give a value of 2.0 for 17 km (as suggested by Hutton and Boore) and 3.0 for a distance of 100 km (as used by Båth). At the reference (anchoring) distance, the same amplitude will correspond to the same magnitude in Norway and California. We return below to the question of selecting an appropriate value for $K(R_{ref})$ for this study.

DATA

The earthquake recordings used in this study are listed in Appendix 1, comprising altogether 741 records from 21 stations and 195 earthquakes occurring in and around Norway between 1971 and 1989. The epicentral distances covered are in the range 20 to 1600 km. Stations and epicenters are shown in Figure 1, resulting in a ray path pattern covering the entire Norway and adjacent areas. The stations are also listed separately in Table 1, together with the number of records from each station and the station corrections resulting from the inversion of one particular subset of the data.

Originally, a much larger data base was considered, based on available earthquake catalogues since 1971 (Bungum *et al.*, 1990). In doing this, we identified essentially all events with a reasonable possibility for providing records above the noise level for at least one digitally recording seismic station, which resulted in a range of magnitudes between 1 and 5. That information was then combined with information about the time periods of recording for the different stations in Norway (Havskov *et al.*, 1990), which reduced the number of possibly useful records.

For each event selected, expected arrival times for the different regional phases were calculated from standard travel time tables. A desired data interval was then computed, covering a time window from 30 sec before the first P-arrival (to provide noise estimates) to 30 sec after the time corresponding to a group-velocity of 1.8 km/s (to provide data for Q-studies). The selected data intervals were then extracted from offline storage media and loaded into a computer data base in a common, compact and easily readable format. During this process all available digital data were included, without any further check on quality and usefulness. This provided more than 1000 records from more than 200 earthquakes.

The subsequent interactive analysis, to be described in more detail below, included also a quality screening through which clipped and noisy recordings were identified and excluded. Recordings containing interfering events were also excluded at this stage. This resulted in the 741 records mentiond above, ready for the subsequent M_L analysis. All of these records are from vertical components, and only a limited number of these are from stations that also provide horizontal component records.

The distribution of the selected data in magnitude-distance space is shown in Figure 2. One unavoidable characteristic of such distributions is that small earthquakes are more often recorded at shorter distances, while larger earthquakes generally have more distant recordings. This trend is amplified if the dynamic range of the sensors is small, leading to clipping of strong ground motions and poor signal-to-noise ratios for weak motions. It is desireable to work with data sets with a lowest possible correlation between magnitude and distance (Joyner and Boore, 1981; Dahle et al, 1990). The data shown in Figure 2 have a correlation coefficient between magnitude and distance of 0.46.

DATA ANALYSIS

In following the methodological approach outlined above, we analyzed the selected data as follows: (1) convert each (vertical) record into a synthesized Wood-Anderson (SWA) seismogram, and read the maximum zero-to-peak amplitudes of the S-wave train (normally L_g), (2) evaluate from independent data the ratio between horizontal and vertical motion for the purpose of compensating for this effect (real WA seismograms are all horizontal), (3) select a reference distance for connecting to Richter's M_L definition, (4) read the maximum S-wave (L_g) amplitudes from the original uncorrected seismograms, and then convert to ground motion, and (5) perform a linear regression analysis as outlined above. Even though points (2) and (3) do not influence the determination of the attenuation terms, they are still necessary for establishing the resulting M_L formula. Point (4) is needed for facilitating the use of amplitudes from uncorrected seismograms, and in particular analog records.

In the following we will cover each of these points in more detail.

Synthesized Wood-Anderson seismograms

The main problem in creating the SWA records is the fact that the WA torsion seismographs are more broad band than the mostly short-period seismometers (velocity transducers) used in recording our data. Since the deconvolution of the instrument response and the convolution with the WA response is performed in the frequency domain, a proper prefiltering reflecting the frequency limitations of the recording systems becomes very important in order to avoid instabilities. For the regional microearthquake networks in southern, western and northern Norway (recording at 50 Hz) we have used a passband of 0.8 - 20 Hz, for the regional arrays NORESS and ARCESS (recording at 40 Hz) 0.8 - 15 Hz, for NORSAR (recording at 20 Hz but with an anti-alising filter at 5 Hz) 0.2 - 5 Hz, and for the NORESS intermediate-period (broad band) data (recording at 10 Hz) we have used a filter at 0.02 - 2 Hz. Table 1 shows the number of records used from each of these systems.

In addition to synthesizing WA seismograms, which was done interactively in order to secure the highest possible quality, a considerable effort was also invested in acquiring the right system response functions (in complex form). Because of frequent changes for some of the stations, this involved keeping several hundred different response functions on file. Of similar importance of course is the Wood-Anderson response, where the frequency response is simple and well known (natural period 0.8 sec, damping ratio 0.8). It has been known for some time, however, that the static magnification of the WA seismographs probably is lower than the theoretical value of 2800 (Bakun and Lindh, 1977; Luco, 1982; Hutton and Boore, 1987; Boore, 1989). Convincing evidence in this respect has now been forwarded by Urhammer and Collins (1990), showing that the magnification of the Wood-Anderson seismographs is 2080 rather than 2800 and that the proper damping ratio is 0.7 rather than 0.8. We have, in accordance with this finding, used a magnification of 2080 and damping ratio of 0.7 when creating our SWA records, yielding magnitudes 0.13 units below those obtained with the earlier value.

The reading of the maximum amplitudes (zero-to-peak) of the seismograms is both simple and reliable when done interactively (manually) in the way it was done in this study. Naturally, both the time and period of the maximum wave of the SWA seismograms, in some cases, can be quite different from what would appear on the uncorrected records.

Horizontal vs. vertical motions

The recording capability for the majority of stations contributing to this study is limited to vertical component recording. Realizing that the original *Richter (1935; 1958)* definition of M_L is for horizontal components of motion, the strategy for this study was to obtain the horizontal to vertical component relationship in a sparate analysis for stations where both components are available. The vertical amplitudes should then be corrected according to this relationship by assuming (preferably) a constant correction factor, thus providing regression results for the horizontal component as required.

To this end, we compared amplitudes of vertical and horizontal components for the available three-component seismograms. A total number of 126 three-component recordings from 100 events for the stations NAO, NRAO, ARAO and LOF were available for this. For each three component record we computed the fraction

$$F_{h,z} = \frac{0.5\,(log A_{ns} + log A_{ew})}{log A_z} \qquad (7)$$

where A_{ns} and A_{ew} are amplitudes from the two horizontal components and A_z from the vertical component. A plot of the data points is shown in Figure 3, demonstrating in fact that the difference in size between horizontal and vertical components in this case is insignificant. The mean value of the ratio is 1.008 and the correlation coefficient is 0.99. In accordance with this, the vertical amplitudes are used in our study as if they were horizontal.

Reference distance

We have already introduced the concept of the reference distance in equations (3) and (4), and indicated that a value of 100 km would be inappropriate because of the significant regional differences in attenuation between Norway and Southern California at that distance. The solution to this problem is of course to choose a distance that is small enough to ensure that earthquakes with similar energy release will create the same size ground motions (as measured on a WA seismograph) in the two regions. That may sound simple, but it is not.

The first condition that must be fulfilled in this respect is that near-source ground motions are comparable for wave propagation through the late Cenozoic rock formations in California and the Precambrian and Paleozoic rocks in Norway. Campbell (1989) has recently published evidence in support of this, finding that for earthquakes in the same magnitude range as ours, the near-source accelerations in eastern North America are consistent with predictions based on Californian observations, once site effects and differences in magnitude scales are accounted for.

A second condition is that Richter's A_0 values are sufficiently reliable at hypocentral distances of less than 100 km. That is probably not the case, but we can solve this problem (as already mentioned) by using the more reliable values of Hutton and Boore (1987). Using their A_0 values, which are identical to Richter's at a distance of 100 km, a magnitude 3.0 earthquake should be recorded with an amplitude of 10 mm at a reference distance (R_{ref}) of 17 km. Hutton and Boore recommended this value be used in a situation like ours, securing a sufficient near-source anchoring.

A third condition, however, is that our local attenuation function can be evaluated with sufficient precision down to the suggested reference distance. If this is not the case, a larger R_{ref} should be chosen. Our average depth of 16 km of course immediately precludes using any reference distance less than about 30 km. Essential here is our distribution of hypocentral distances (see Figure 2), showing only 3 records within 20 - 40 km, 6 within 40 - 60, 10 within 60 - 80, and 10 within 80-100 km. We have consequently selected a R_{ref} value of 60 km, balancing the requirement of a near-source reference distance with data quality considerations.

Using this reference distance of 60 km, the resulting A_0 curves (as taken from the regression analysis discussed below) for focal depths of 0 and 20 km are shown in Figure 4 (solid lines), along with those of Hutton and Boore (1987) for comparison (dashed lines). It is seen there that the difference between the $-log A_0$ curves never exceeds 0.15 magnitude unit for any distance within 100 km (note that they are plotted vs. *epicentral* distance). For larger distances the difference in anelastic attenuation (b-values) results of course in divergence of the curves, and a difference on the order of one magnitude unit at a distance of 870 km. From equation (6) we see that $K(R_{ref})$ obtained for $R_{ref} = 60$ km is 2.68.

Given these similarities in the near field, the main uncertainty with respect to the anchoring is therefore not tied to the determination of R_{ref} but rather to the underlying assumption of near-source ground motion equivalence.

Regression analysis

Using the entire data base of 741 seismograms from 195 earthquakes, a linear regression analysis was performed as outlined above. However, since earthquakes with less than two recordings do not contribute in the estimation of a and b in equation (4), we chose to use only events with a minimum of 3 recordings to also help with azimuthal averaging. The effective size of the data base then reduces to 624 seismograms from 120 earthquakes.

Even though epicenter estimates are available for our events with a sufficient precision (generally within $\pm$ 5-15 km), focal depths are not available for the majority of them. We know, however, the focal depth distribution fairly well in the region (Bungum *et al.*, 1990), and on this basis we chose to use a value of 16 km for all of the events when estimating hypocentral distances for the regression. This factor is of course of importance only for the closest epicentral distances, and separate tests have shown that the effect is marginal within the range of realistic focal depths.

The results of this inversion for different subsets are discussed below and values for a and b are given in Table 2. While a-values like these are commonly found, such low b-values are possible only in truly intraplate, high-Q areas (Kvamme and Havskov, 1989; Dahle *et al.*, 1990). The southern California value of Hutton and Boore (1987), in comparison, is 0.00189, and the central California value of Bakun and Joyner (1984) is 0.00301.

Individual station corrections constrained to have zero average are estimated during the M_L regression, and given with standard deviations in Table 1. The station corrections are all in the range -0.21 to +0.22 magnitude units, and with a standard deviation which varies from 0.05 to 0.10. The variation in the standard deviation is probably attributable to the difference in the number of events recorded at the different stations.

Amplitudes from observed (uncorrected) seismograms

The computation of synthesized Wood-Anderson amplitudes is not feasible in all routine magnitude assessments, in particular when analog records are considered. We have therefore also measured the maximum (L_g) amplitudes (and periods) on the observed (raw) seismograms, and corrected these amplitudes for system response. Note that this is different from measuring amplitudes from response corrected (ground motion) seismograms, which should be expected to give values (ignoring gain differences) closer to the WA seismograms.

The "observed" amplitudes are shown in Figure 5 together with the SWA amplitudes. A maximum likelihood regression analysis (assuming the same size errors in the two axes) gives the following relation

$$log A_{wa} = 0.925 \cdot log A_{obs} - 2.32 \tag{8}$$

where A_{wa} is the SWA amplitude and A_{obs} is the response corrected ground motion amplitude in nanometers.

This regression is quite reliable and therefore very useful for adapting our M_L relations to situations when SWA seismograms cannot easily be obtained. The systematic difference between the two amplitudes is due to the fact that the SWA amplitudes are often picked for waves with longer periods thereby yielding larger ground motion amplitudes.

It should be noted here, however, that one factor contributing to the small scatter in Figure 5 is the fact that most of the data are taken from recording systems that have reasonably similar (short period) response characteristics. Equation (10) below is therefore not necessarily applicable to other systems.

REGIONAL VARIATIONS

As can be seen on Figure 1, some ray paths extend into offshore regions, entering geologic features such as the Viking Graben in the North Sea, and crossing the continental margin along the entire western and northern coastline of Norway (Hansen *et al*, 1989; Bungum *al.*, 1990). The propagation of L_g waves across such strong variations in the crustal waveguide usually results in a strong deterioration of the L_g phase (Kennett *et al.*, 1985; Regan and Harkrider, 1989; Bostock and Kennett, 1990). The continental margin areas, and the graben structures of the North Sea represent such varying conditions for L_g propagation, resulting in some instances in a blockage of the L_g waves strong enough to make the S_n phase the strongest one in the seismogram.

For this reason, and also because we wanted to see if significant variations could be found within the more strictly continental areas, we inverted our data for a number of subsets as shown in Table 2. Results are presented there for (1) all data, (2) continental paths only, (3) distances less than 1000 km, (4) epicenters north of 63° N using all stations, (5) epicenters south of 63° N using all stations, (6) epicenters north of 63° N using only the northern stations, (7) epicenters south of 63° N using only the southern stations, and (8) readings with group velocities equal to or below 3.8 km/s. The number of (effectively contributing) observations in each of these cases are listed in the right hand column of Table 2.

For all subsets, the data were inverted with all parameters free, and for an *a*-value fixed to 1.0. The reason for this is that there is often a trade-off between the *a*- and the *b*-values estimated in the regression. In keeping the *a*-values fixed it is then easier to judge the significance of the differences in the *b*-values as a function of regional variation in anelastic attenuation. Some more specific comments on the results in Table 2 are presented in the following.

The subset that should be expected to provide the best selection of more purely continental L_g paths is subset 2 in Table 2. The results indicate only a small difference as compared to the regression over the entire data base. This difference in fact illustrates the trade-off between the a-value (spreading) and the b-value (anelastic attenuation). The resulting values are only marginally outside the estimated error limits. The value estimated for a is actually closer in this case to the theoretical value of 0.83 expected for an Airy (L_g) phase. However, the resulting differences in the $-logA_0$ term amount to less than 0.1 magnitude units at any distance. Similar results are obtained for subset 3, with epicenter distances less than 1000 km, which serves to exclude some of the distant events located in oceanic crust. For a fixed a-value, Table 2 shows a slight increase in b from subset 2, probably because some of the ray paths are sampling more offshore areas.

Subsets 4-7 were created to look for possible regional differences with respect to the northern and the southern areas (see Figure 1). When considering the increasing uncertainties (due to decreasing data sets), there is no basis for suggesting different a and b values for different regions.

The final test (subset 8) include data sorted on apparent group velocity for the maximum amplitude arrivals of the recordings. This kind of sorting should make it possible to exclude some of the situations in which S_n (or S_g) dominates the seismogram instead of L_g, which normally has a group-velocity of around 3.5 km/s. For subset 8 we have therefore selected records with group-velocities of $\beta \leq 3.8$ km/s. As can be seen from Table 2, this selection does not yield results significantly different from subsets 1 and 2, showing that S_n contamination is not seriously affecting our results.

RESULTING MAGNITUDE RELATION

Having now determined the $-logA_0$-values (in terms of a and b), the reference (anchoring) distance R_{ref} (60 km), and the horizontal to vertical ratio (1.0), a simple magnitude relation is obtained as:

$$M_L = logA_{wa} + 0.91\ log(R) + 0.00087\ (R) + 1.010 + S \qquad (9)$$

where $R = \sqrt{\Delta^2 + h^2}$ is hypocentral distance, Δ is epicentral distance, h is source depth, and station corrections S can be found in Table 1. The a and b values are taken here from Table 2, subset 2, which provides more purely continental L_g travel paths. Equation (9) therefore does not apply correctly (neither would subset 1) to offshore travel paths subjected to L_g blockage, a problem which we will return to in the Discussion.

In Figure 6 we have plotted the derived L_g attenuation for Norway together with the Hutton and Boore (1987) relation for southern California, and up to a larger distance than shown in Figure 4. The data points plotted are our SWA readings corrected for the M_L and S terms in equation (4) using equation (9), and show the distribution of all observations about the $-logA_0$ curve according to equation (3). The curve and the points clearly show the difference in attenuation in southern Californian as opposed to that of L_g phases in Norway, a difference which amounts to one full magnitude unit at a distance of 870 km and 1.7 units at 1500 km.

The regression of logarithmic SWA amplitudes provides, in addition to attenuation and station corrections, new estimates of the magnitudes for all of the events in the data set. The largest of these, with M_L above 3.5, are listed separately in Table 4 together with their epicentral locations.

The residuals in the regression of the SWA amplitudes are essentially magnitude residuals, as may be deduced from equation (1). The residual distributions versus epicentral distance and regressed magnitude, respectively, are shown in Figures 7a and 7b. The dotted lines indicate standard deviations of about 0.17, and the plots show no particular trend with respect to distance or magnitude.

When replacing the SWA amplitudes (A_{wa}) with gain-corrected amplitudes from observed (raw) seismograms (A_{obs}) in nanometers by combining equations (8) and (9), the following relation is obtained:

$$M_L = 0.925 \; logA_{obs} + 0.91 \; log(R) + 0.00087 \; (R) - 1.310 + S \tag{10}$$

Discussion

One of the limitations in the present work is that to a large extent we use short period data (with cutoffs as high as 0.8 Hz) for synthesizing the Wood-Anderson seismograms. This could, in particular at shorter distances and for larger events, lead to some underestimation of the SWA amplitudes and thereby to a negative bias in the resulting magnitudes. However, since the largest earthquake in our data base is only M_L 5.0, we expect this effect to be modest.

The stability of our analyses with the different subsets tested above reflects quite positively on our results with respect to their usefulness and applicability. An essential factor behind the stability is of course the good distribution of both stations and epicenters, yielding a good coverage in magnitude and distance (taking into account that this is a low-to-intermediate seismicity region). In addition, our data ensures a good azimuthal coverage, which is quite important with respect to averaging of path (tectonic) as well as source (radiation pattern) effects.

We interpret, however, this stability first of all as a reflection of the fact that our analysis essentially is resolving attenuation characteristics *between* the seismic stations, and not between the epicenter and first station. For offshore epicenters and onshore stations we often sample only the continental parts of the path, except in the cases when several stations along the coast record an event at different epicentral distances. This effect creates a "continental bias" which can explain some of the observed stability, and the result is an underestimation of magnitudes for some of the offshore events. The problem of L_g blockage due to the crustal waveguide variations imposed by grabens and continental margins are consequently not resolved in the present study.

A proper assessment of local magnitudes (based on maximum amplitude within the S-wave train) for wavepaths crossing tectonic features that may cause L_g blockage therefore requires an approach within which the transfer function for waves passing through such areas is established. Such an approach requires an independent assessment of the size of these earthquakes either through the use of teleseismic arrivals (usually not available for these events) or P_g/P_n arrivals, or by obtaining S-wave train observations (including both S_n and L_g) from both sides of the L_g blocking area. Data of such kind would make it possible to establish correction terms for source areas with L_g blockage problems, included as adjustments to our existing magnitude formula.

In the mean time, and in spite of the fact that L_g blockage has been firmly established as causing a reduction in the amplitude across a relatively short transition zone, the local magnitude formula to be adopted for observatory practice in Norway would have to be one based on travel paths propagating essentially within the continental crust. Hopefully, corrections for some of the offshore paths will be available later.

Up to now, we have used as mentioned earlier Båth's relation for M_L magnitudes in Norway. When using this relation on our raw data amplitudes we find that they are in fairly good agreement with our new SWA-based M_L values, as shown in Figure 8. It should be noted, however, that we have computed the Båth M_L values using a fixed period in order to avoid the instabilities (mentioned above) caused by the frequency sensitivity of Båth's relation. Therefore, when comparing with earlier reported magnitudes based on that relation, the scatter becomes much larger.

From Figure 8 we see that the Båth magnitudes are generally about 0.4 units higher than the new ones, an offset which can be explained by the combined effect of using a smaller anchoring distance than Båth (60 instead of 100 km) and a different value for the WA gain (2080 instead of 2800). When considering the fact that Båth *et al.* (1976) developed their relation exclusively from analog data, and when not considering the problems tied to the frequency dependence of the correction tables, we can therefore conclude now that their relation is impressively accurate.

The present study has to some extent been inspired by the need within the petroleum industry for reliable earthquake hazard estimates offshore Norway (Bungum and Selnes, 1988). Such estimates are largely based on M_S magnitudes obtained from historical data through a major reassessment of felt areas from earthquakes, and calibrated against M_S measurements from instrumental data (Muir Wood and Woo 1987). Within this context, and for other reasons as well, a reliable relation between this M_S scale and our new M_L values is therefore of much importance. For earthquakes down to magnitude 3.5, Figure 9 presents this magnitude comparison, with the data listed separately in Table 4. A maximum likelihood regression analysis of M_L versus M_S (assuming the same sized errors in both axes) resulted in the equation

$$M_S = 0.83 \cdot M_L + 1.09 \tag{11}$$

This result is in good agreement with the relation $M_S = 0.85 \cdot M_L + 0.60$ obtained earlier by Bungum (1987), using M_L magnitudes determined by the Båth formula. The difference of 0.5 in the constant coefficient is consistent with the mean difference between the new M_L scale and the Båth M_L scale discussed above.

CONCLUSIONS

Almost 20 years of digital data, comprising 741 records from 195 earthquakes in the magnitude range 1-5, have been used in developing a new M_L scale for Norway. The data base includes records from 21 stations, and cover distances from 20 to about 1500 km. We have converted all records (covering the maximum of the L_g wave train) to synthesized Wood-Anderson seismograms, and inverted for L_g wave attenuation (distance corrections), individual earthquake magnitudes, and station corrections. The attenuation has been developed in terms of Richter's $-logA_0$ values, expressed through a geometrical spreading term a and an anelastic attenuation term b. We conclude that

(1) When using the entire data base, including also some wave paths affected by L_g blockage problems connected to offshore graben structures and the continental margin, we find an a-value of 1.02 and a b-value of 0.00080. A subset of more purely continental wave paths give values of 0.91 and 0.00087. Differences in magnitude computed from any of these two a and b value sets, are less than 0.1 magnitude units at any distance.

(2) Geometrical spreading terms (a-values) around 1.0 are commonly found in many different tectonic environments, while anelastic terms (b-values) as low as 0.0008 are specific for high-Q intraplate environments such as Norway. In comparison, b-values in California are typically 2-4 times larger, indicating the same (inverse) ratio with respect to average effective Q.

(3) Due to spatial sampling problems we have not in the present study been able to resolve satisfactorily the problems tied to L_g blockage for partially offshore wave paths. Some of the earthquakes occurring sufficiently far from the Norwegian coastline will therefore (still) be underestimated in magnitude when using our new M_L formula. Additional correction terms for these events will have to be developed later.

(4) When anchoring a new M_L scale to Richter's definition it is necessary to define a reference distance at which the same sized earthquake is assumed to produce the same ground motion, and with large differences in regional L_g wave attenuation a near-source reference distance is required. Because of limitations in our data at short distances we have in the present study set this reference distance to 60 km.

(5) Given this reference distance, the difference between the correction factors of Hutton and Boore (1987) for southern California and ours for Norway never exceeds 0.1 magnitude units for any distance within 100 km. At 870 km, however, the difference amounts to one full magnitude unit, and at 1500 km to 1.7 units.

(6) It has been known for a long time that the magnification of the Wood-Anderson seismograph probably is less than the theoretical value of 2800. Urhammer and Collins (1990) have now convincingly established that the value is 2080, and we have adopted the same value in the present study. This factor leads to a reduction of all magnitudes by 0.13 units.

(7) All station corrections are found to be within ± 0.22, and 0.10 or less for 11 of the 21 stations used. Regression comparisons with M_L values computed from the earlier used M_L scale and with M_S values available for a subset of our data have provided the necessary ties to the past.

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Table Captions

Table 1. Stations used in the M_L analysis, with code, location, number of earthquake recordings, and individual station corrections with standard deviations. Station 1 and 2 are subelements of the teleseismic NORSAR array (1970-present), 3 and 4 are the NORESS (1984-present) and the ARCESS (1988-present) regional arrays, 5-10 are from the Southern Norway Seismic Network SNSN (1979-1983), 11-15 are from the Western Norway Seismic Network WNSN (1985-present), and 16-21 are from the Northern Norway Seismic Network SEISNOR (1987-present) (Havskov *et al.*, 1990).

Table 2. Values for coefficients a and b obtained for different data sets. The last column gives the number of records (effectively contributing) in the data set. The fixed a-value was set to 1.00 for all subsets analyzed.

Table 3. Origin time, latitude, longitude, M_L magnitudes and number of records used in the estimation, for events with new M_L values greater than 3.5.

Table 4. Events used in the M_S versus M_L comparison (Figure 9).

Figure Captions

Figure 1. Seismic stations (left), and epicenters of events and raypaths between events and stations (right) used in the M_L analysis.

Figure 2. Magnitude - distance distribution of events used in the M_L analysis.

Figure 3. Plot of the ratio of the horizontal to vertical amplitude using data from 3 component stations NAO, NRA0, ARA0 and LOF.

Figure 4. Regional L_g wave attenuation values ($-logA_0$) vs. epicentral distance as developed in this study for focal depths of 0 and 20 km (fully drawn lines) as compared to corresponding southern California values from Hutton and Boore (1987) (dashed lines). The inserted figure shows a blowup for the nearest 120 km.

Figure 5. Synthesized Wood-Anderson amplitudes vs. amplitudes measured on raw (observed) seismograms corrected for system response. The fully drawn line reflects a maximum-likelihood regression assuming similar errors along the two axes. Dotted lines are the two least squares regressions.

Figure 6. Regional L_g wave attenuation ($-logA_0$) curves obtained in this study (solid line) as compared to the southern California values of Hutton and Boore (1987) (dotted line). The data points reflect the scatter in the synthesized Wood-Anderson amplitudes.

Figure 7. Residual magnitude distributions versus epicentral distance (left) and regressed magnitude (right). Dotted lines are plus and minus one standard deviation.

Figure 8. New M_L values vs. M_L obtained using the Båth *et al.* (1976) relation.

Figure 9. New M_L values vs. M_S for a subset of events. The solid line reflects a maximum-likelihood regression assuming similar errors along the two axes and the dotted lines are the two least squares regressions. See main text for details.

No	Station	Code	Lat	Lon	No	Correction
1	NORSAR	NAO	60.84	10.89	59	-0.15 ± 0.057
2	NORSAR	NC3	61.26	11.41	45	-0.21 ± 0.070
3	ARCESS	ARA0	69.54	25.51	46	0.11 ± 0.055
4	NORESS	NRA0	60.74	11.54	72	0.03 ± 0.045
5	Norefjell	NFJ	60.38	9.56	28	-0.18 ± 0.079
6	Seljord	SJD	59.56	8.61	27	-0.13 ± 0.079
7	Drangedal	DRA	59.10	9.10	23	-0.12 ± 0.083
8	Sørum	SRU	60.06	11.26	17	-0.07 ± 0.097
9	Sarpsborg	SPG	59.35	11.34	26	-0.01 ± 0.078
10	Evje	EVJ	58.58	7.96	14	-0.16 ± 0.096
11	Blåsjø	BLS	59.39	6.83	24	0.15 ± 0.063
12	Odda	ODD	59.91	6.63	34	0.00 ± 0.054
13	Høyanger	HYA	61.17	6.19	34	0.10 ± 0.053
14	Sulen	SUE	61.06	4.76	34	0.16 ± 0.053
15	Karmøy	KMY	59.21	5.25	29	0.22 ± 0.057
16	Namsos	NSS	64.53	11.97	37	0.00 ± 0.053
17	Mo i Rana	MOR	66.24	14.77	24	-0.02 ± 0.061
18	Tromsø	TRO	69.63	18.93	48	0.08 ± 0.053
19	Molde	MOL	62.57	7.55	31	0.07 ± 0.056
20	Lofoten	LOF	68.13	13.52	41	0.10 ± 0.057
21	Kautokeino	KTK	69.01	23.24	48	0.02 ± 0.055

Table 1

No	Data set	a-value	b-value	b-value when $a = 1.0$	No.
1	All data	1.02 ± 0.093	0.00080 ± 0.000092	0.00082 ± 0.000048	624
2	Continental paths	0.91 ± 0.107	0.00087 ± 0.000114	0.00079 ± 0.000059	442
3	Maximum 1000 km	0.89 ± 0.109	0.00101 ± 0.000136	0.00089 ± 0.000065	576
4	N 63° all stat.	0.84 ± 0.160	0.00102 ± 0.000150	0.00089 ± 0.000070	322
5	S 63° all stat.	0.86 ± 0.160	0.00111 ± 0.000290	0.00089 ± 0.000150	302
6	N 63° north stat.	0.76 ± 0.210	0.00122 ± 0.000240	0.00098 ± 0.000110	182
7	S 63° south stat.	0.73 ± 0.160	0.00142 ± 0.000320	0.00097 ± 0.000160	282
8	$\beta_{Lg} \leq 3.8$ km/s	1.07 ± 0.100	0.00074 ± 0.000110	0.00080 ± 0.000060	456

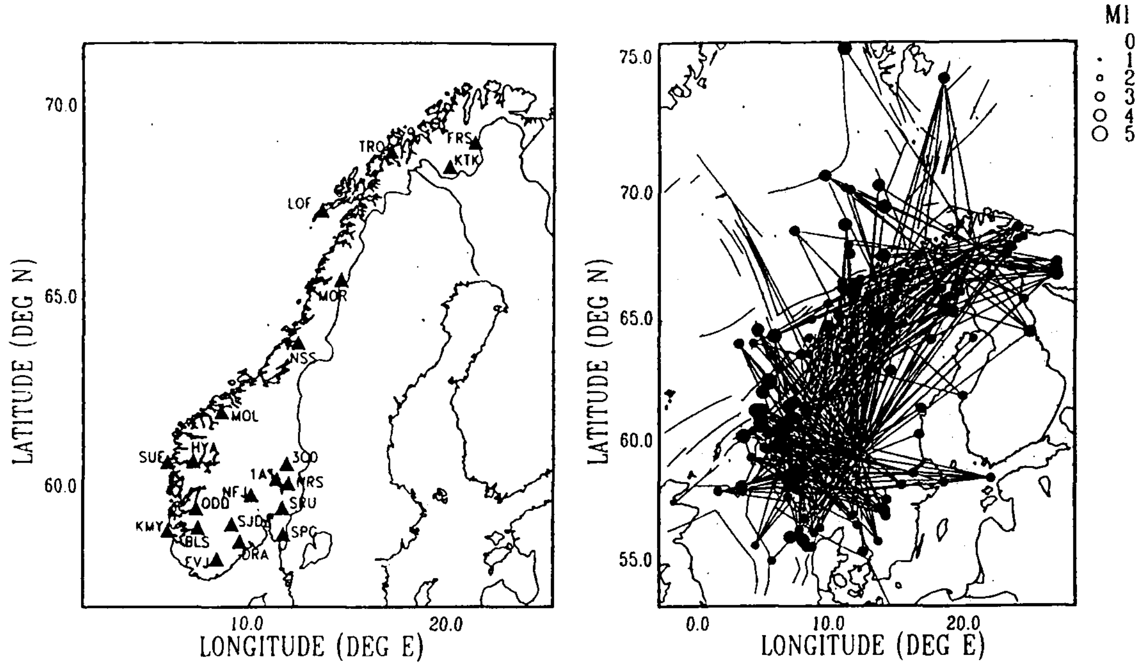
Table 2

	Origin time			Latitude	Longitude	Mag	No
1972	OCT	25	182550.5	70.900N	6.700W	4.10	2
1974	APR	28	125254.0	68.700N	16.200E	3.90	1
1975	JAN	20	104729.1	71.704N	14.205E	3.81	2
1977	APR	06	193145.1	61.734N	2.283E	4.15	1
1977	APR	30	233241.9	68.107N	10.644E	3.50	2
1977	NOV	09	141442.3	63.169N	1.934E	3.76	1
1978	SEP	19	145233.9	62.338N	1.538E	3.70	1
1981	SEP	03	183941.1	69.577N	13.964E	4.04	7
1982	APR	19	094928.0	61.650N	4.325E	3.63	5
1982	JUL	29	001657.8	61.142N	0.809E	4.12	1
1983	MAR	08	184355.7	59.647N	5.387E	4.13	5
1986	FEB	05	175335.3	62.736N	4.668E	4.72	1
1986	APR	04	224235.3	70.889N	8.873E	3.82	1
1986	JUL	14	135037.9	58.457N	13.753E	4.14	4
1986	SEP	01	221125.3	60.803N	2.929E	3.99	2
1986	OCT	26	113444.3	61.626N	3.918E	4.36	2
1987	OCT	31	100914.9	61.105N	4.294E	3.57	5
1988	JAN	31	185142.1	68.086N	9.242E	3.68	11
1988	APR	25	200933.0	78.560N	6.105E	3.60	1
1988	AUG	08	195934.0	63.672N	2.386E	4.96	5
1988	DEC	06	162141.8	77.010N	26.140E	3.74	6
1989	JAN	20	093346.2	57.618N	8.479E	4.01	5
1989	JAN	23	140628.5	61.952N	4.404E	4.82	5
1989	JAN	29	163822.2	59.651N	6.016E	4.41	5
1989	APR	16	063443.6	67.580N	33.680E	3.83	3

Table 3

Origin time				Latitude	Longitude	Ms	Ml
1974	APR	28	125254.0	68.700N	16.200E	4.3	3.9
1975	JAN	20	104729.1	71.704N	14.205E	4.2	3.8
1977	APR	06	193145.1	61.734N	2.283E	4.6	4.2
1977	APR	30	233241.9	68.107N	10.644E	3.9	3.5
1981	SEP	03	183941.1	69.577N	13.964E	4.4	4.0
1982	APR	19	094928.0	61.650N	4.325E	4.1	3.6
1982	DEC	15	064441.3	62.283N	5.368E	4.1	3.5
1986	FEB	05	175335.3	62.736N	4.668E	4.8	4.7
1988	AUG	08	195934.0	63.672N	2.386E	5.3	5.0
1989	JAN	23	140628.5	61.952N	4.404E	5.1	4.8

Table 4



70.0
65.0
60.0
LATITUDE (DEG N)
TRO
FRS
KTK
LOF
MOR
NSS
MOL
SUE
HYA
1AS
300
NRS
NFJ
ODD
SJD
SRU
KMY
BLS
SPG
EVJ
DRA
10.0
20.0
LONGITUDE (DEG E)
75.0
70.0
65.0
60.0
55.0
LATITUDE (DEG N)
0.0
10.0
20.0
LONGITUDE (DEG E)
Ml
0
1
2
3
4
5

Figure 1

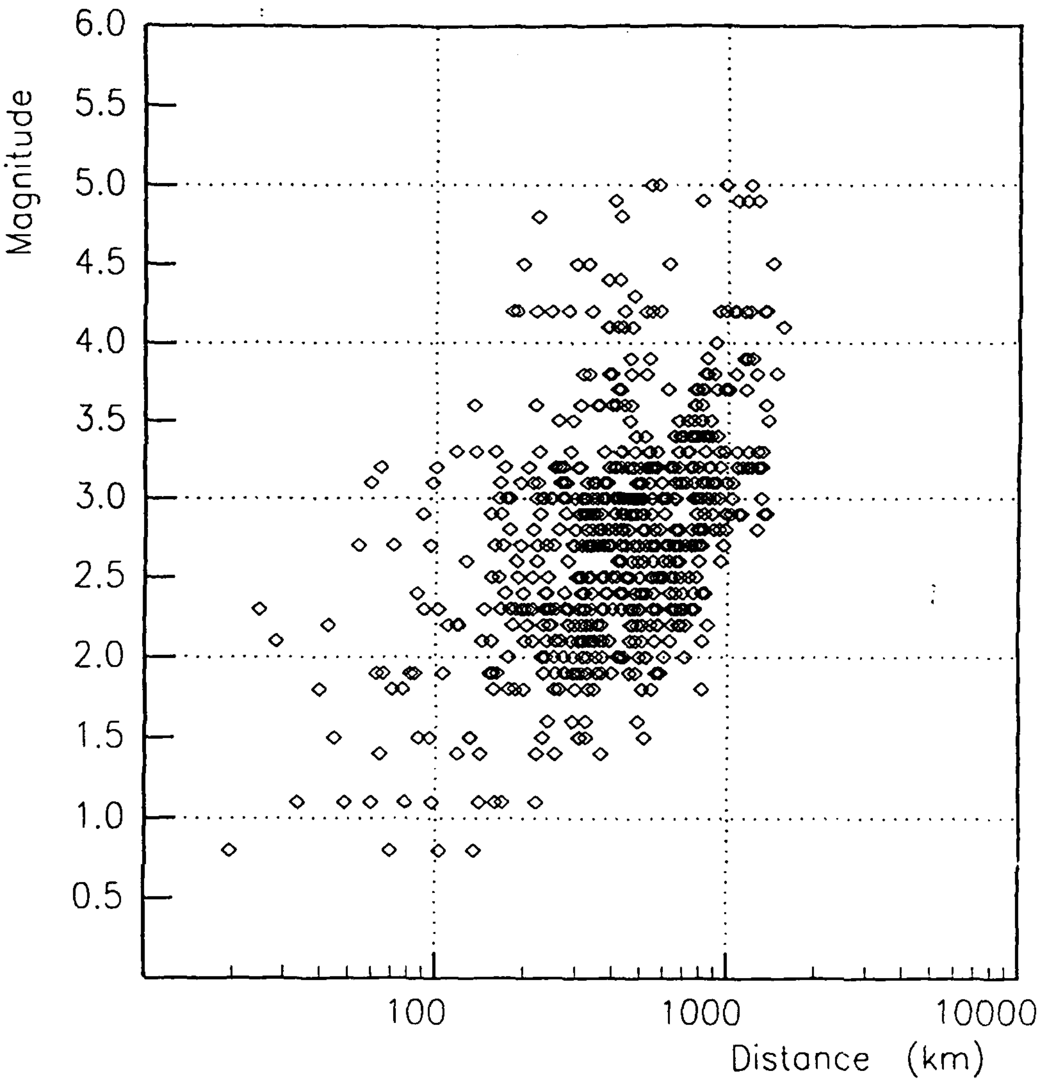

Magnitude
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
100
1000
10000
Distance (km)

Figure 2

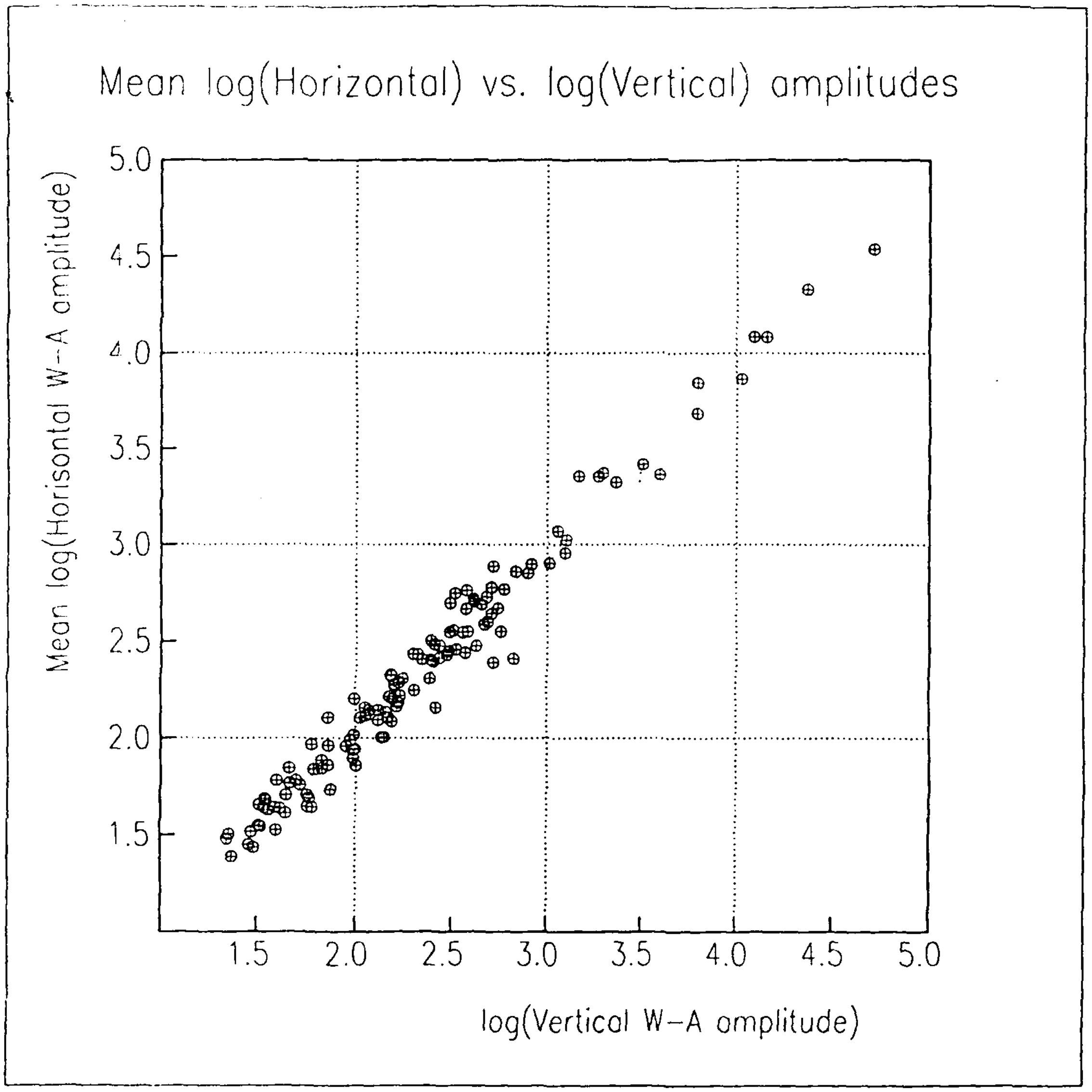
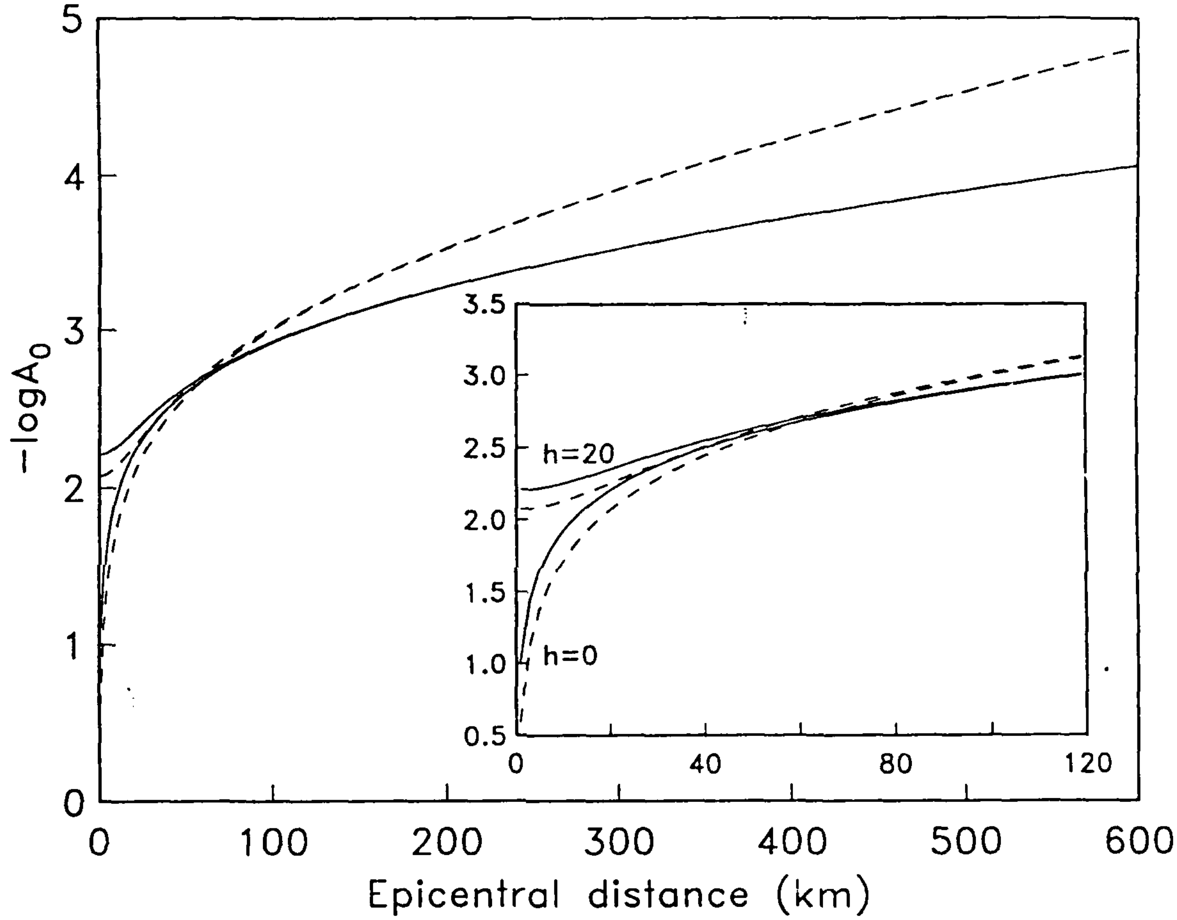
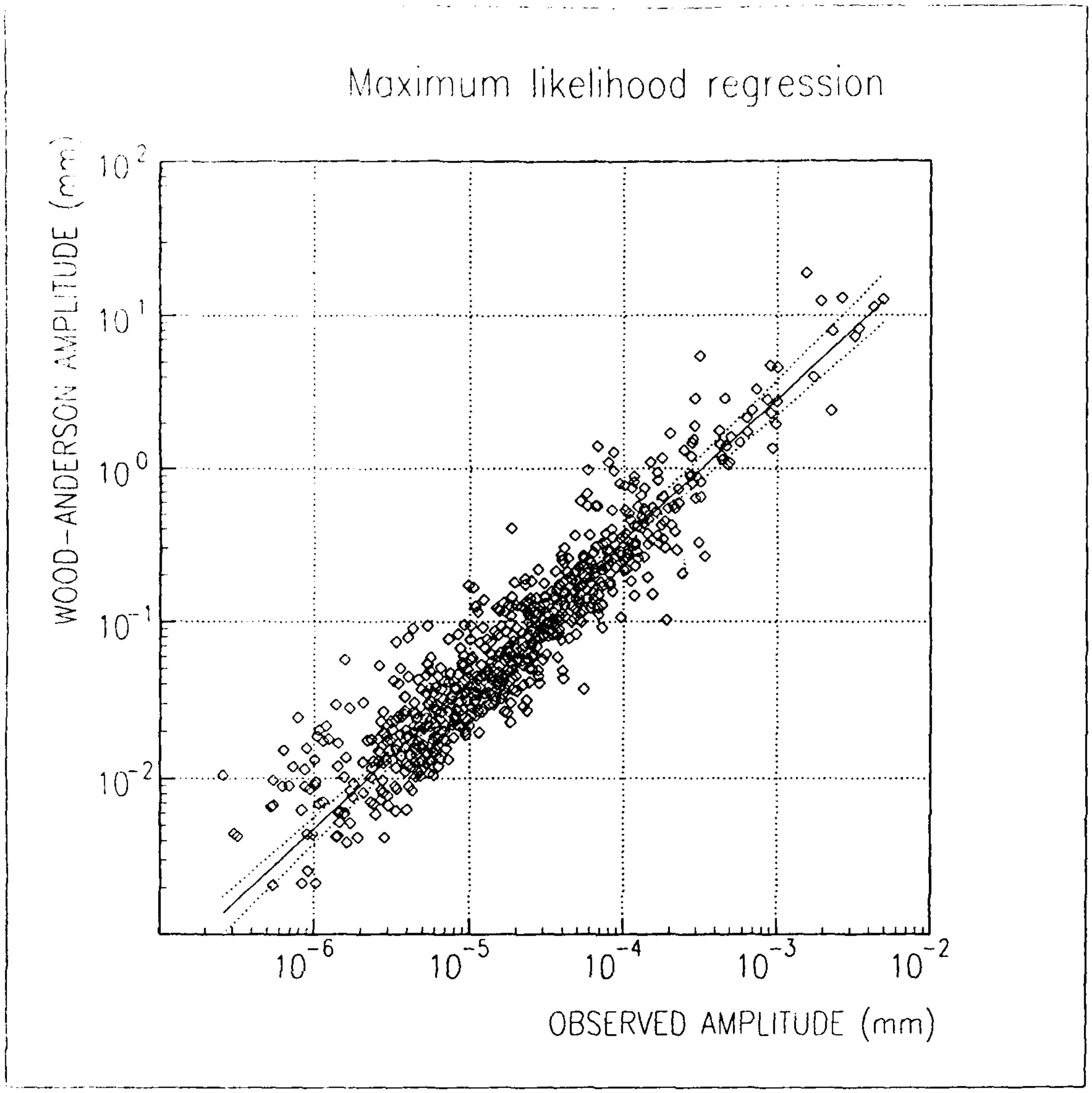

Mean log(Horizontal) vs. log(Vertical) amplitudes
Mean log(Horisontal W-A amplitude)
log(Vertical W-A amplitude)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

Figure 3



5
4
3
2
1
0
$-\log A_0$
0
100
200
300
400
500
600
Epicentral distance (km)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
h=20
h=0
0
40
80
120

Figure 4



Maximum likelihood regression
WOOD-ANDERSON AMPLITUDE (mm)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
OBSERVED AMPLITUDE (mm)

Figure 5

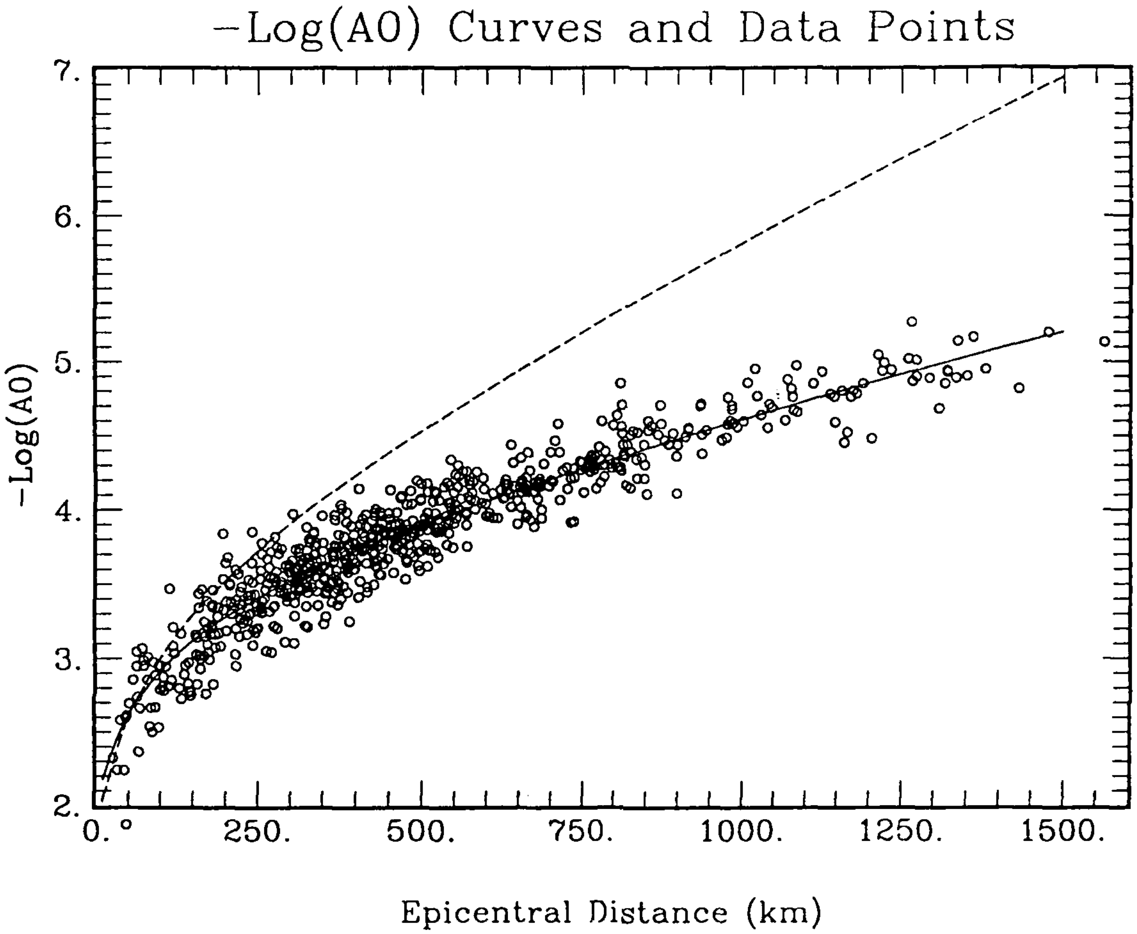

-Log(A0) Curves and Data Points
7.
6.
5.
4.
3.
2.
-Log(A0)
0.
250.
500.
750.
1000.
1250.
1500.
Epicentral Distance (km)

Figure 6

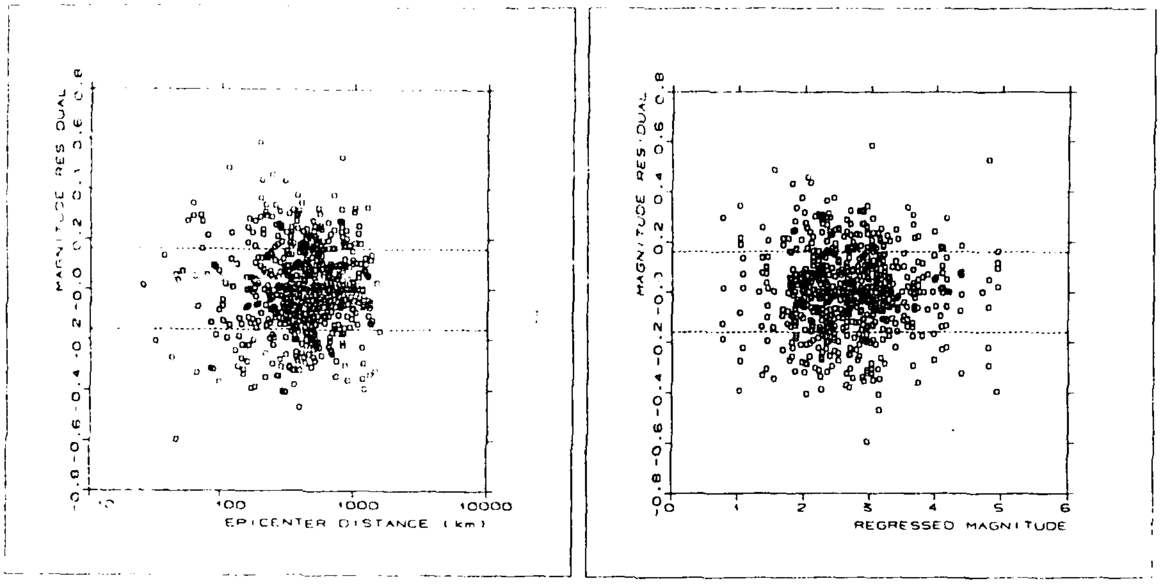

MAGNITUDE RES DUAL
EPICENTER DISTANCE (km)
100
1000
10000
MAGNITUDE RES DUAL
REGRESSED MAGNITUDE
0
1
2
3
4
5
6

Figure 7

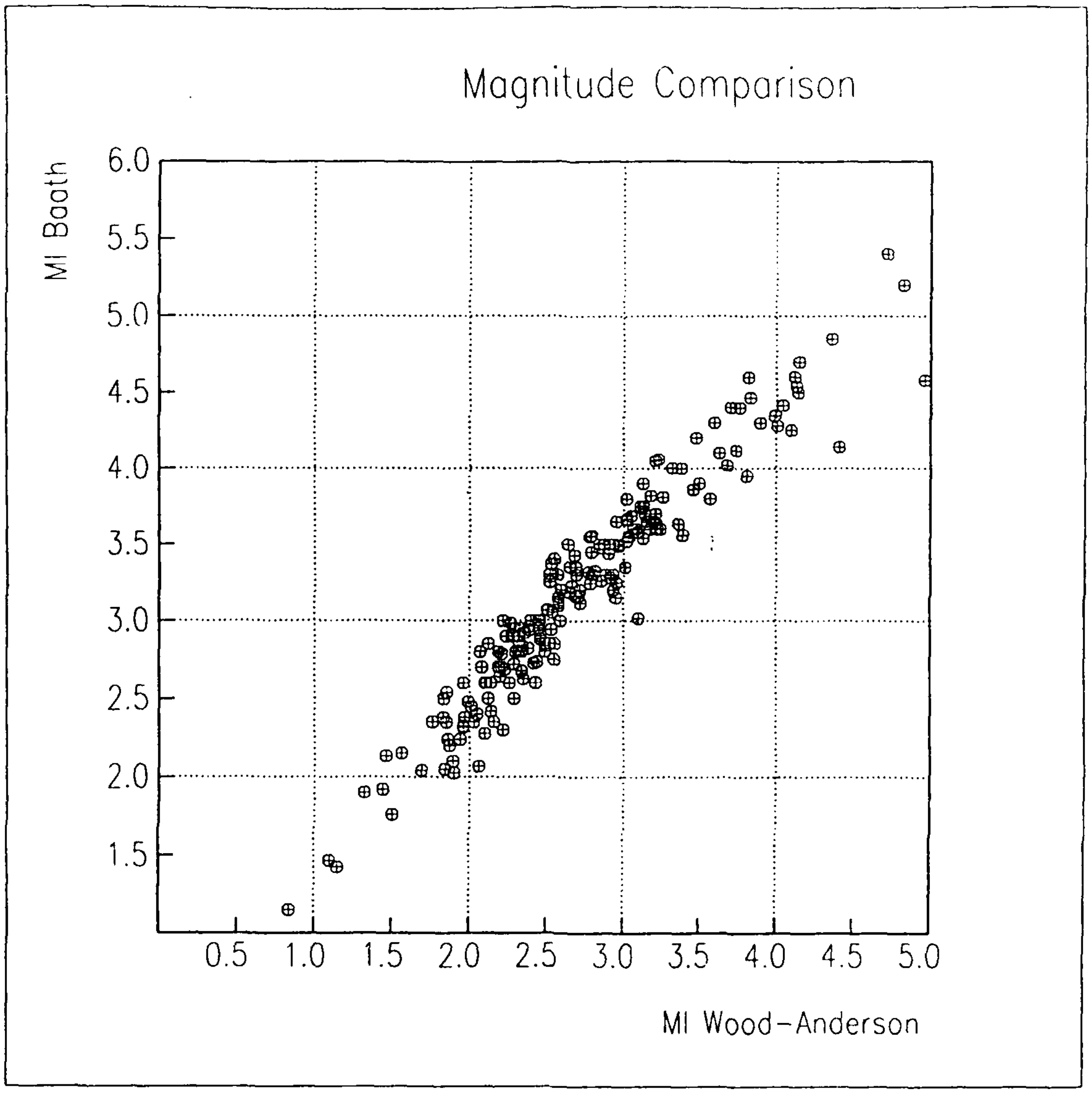
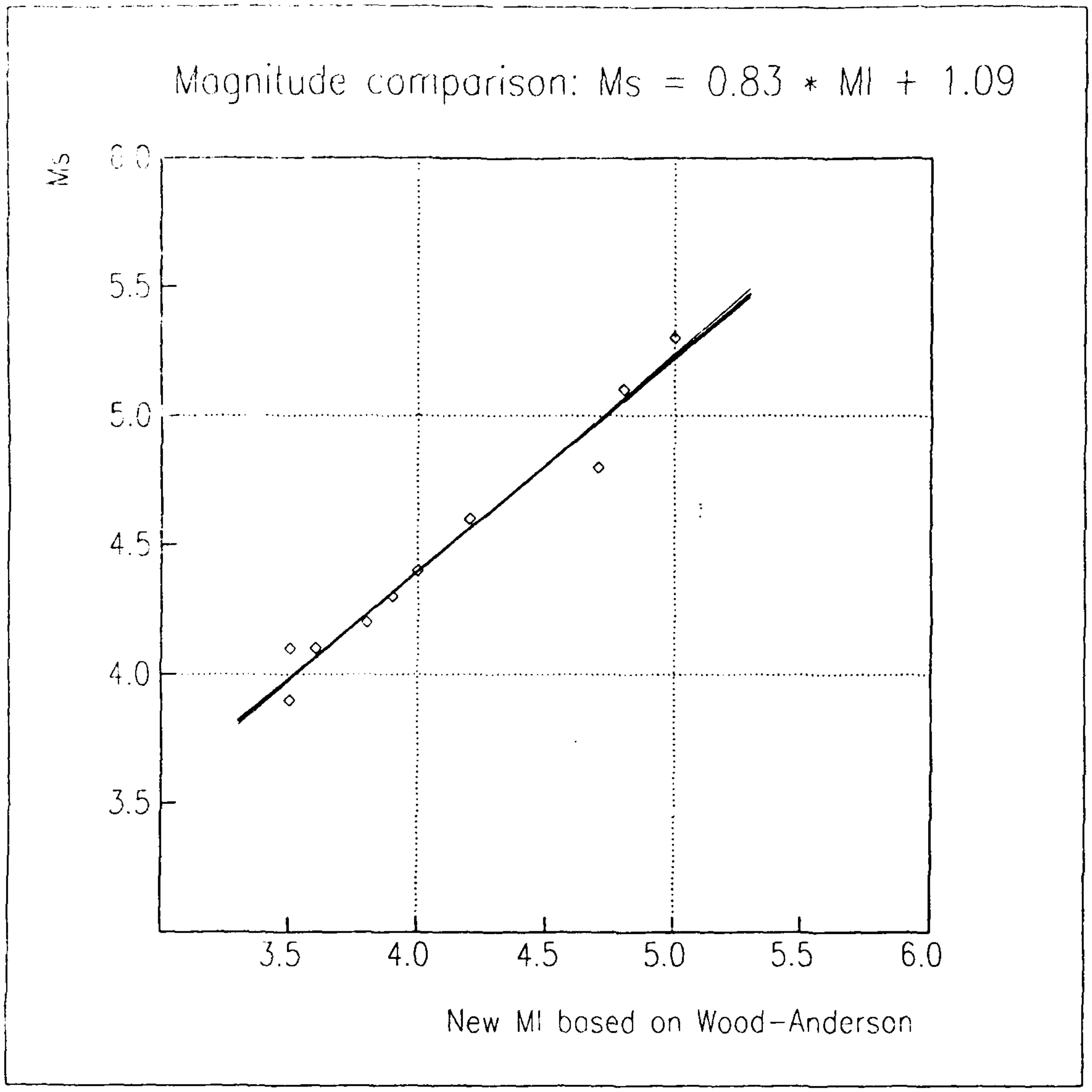

Magnitude Comparison
Ml Baath
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Ml Wood-Anderson

Figure 8



Magnitude comparison: Ms = 0.83 * Ml + 1.09
Ms
6.0
5.5
5.0
4.5
4.0
3.5
3.5
4.0
4.5
5.0
5.5
6.0
New Ml based on Wood-Anderson

Figure 9

Appendix A

List of Recordings Collected and Processed

Explanation of Codes and Parameters Listed

Header line for each event

```
1977 APR 06  ISC 193145.1 61.734N   2.283E  10 4.4 ISC 3.9 UPP 4.6       4.2 M1W

Par no.  1: [1977]        Year
Par no.  2: [APR]         Month
Par no.  3: [06]          Day of Month
Par no.  4: [ISC]         Institution determining time and location
Par no.  5: [193145.1]    Origin time hhmmss.s of earthquake (GMT)
Par no.  6: [61.734N]     Epicenter latitude
Par no.  7: [2.283E]      Epicenter longitude
Par no.  8: [10]          Focal depth in kilometers
Par no.  9: [4.4 ISC]     Magnitude and reporting agency
Par no. 10: [3.9 UPP]     Magnitude ML and reporting agency
Par no. 11: [4.6]         Magnitude MS
Par no. 12: [4.2 M1W]     NORSAR Richter compatible magnitude ML
```

Record line for each station

```
01A01   471.5  285.9                       Low gain, no P-arrival (LF)

Par no.  1: [01A01]:      Recording station code
Par no.  2: [271.6]:      Epicenter distance in km
Par no.  3: [285.9]:      Azimuth i degrees
Par no.  4: [Comments..]  Comments to data or processing
```

Abbreviations and codes

```
BER   : University of Bergen, Seismological Observatory
ISC   : International Seismological Centre
NAO   : NORSAR Scientist
BKH   : Norsar Analyst
PDE   : USGS Preliminary determination of epicenters
UPP   : University of Uppsala
NOP   : University of Helsinki scientist
01A01 : NORSAR instrument 01A01
```

```
1971 NOV 08  ISC 232444.4 62.946N   5.069E  33 4.5 PDE         4.5        3.0 MlW
         DIST   AZIM                                   Comments....................
03C00    380.6  302.3                                  Saturated, no P-arrival (LF)
01A01    385.0  310.0                                  Saturated, no P-arrival (LF)

1972 OCT 25  ISC 182550.5 70.900N   6.700W  33 5.3 PDE         5.1        4.1 MlW
         DIST   AZIM                                   Comments....................
03C00   1333.9  325.7                                  Ok (LF)
01A01   1361.1  328.5                                  Ok (LF)

1973 FEB 13  ISC 000512.1 65.787N  18.887E     3.4 PEN 3.1 PEN            2.5 MlW
         DIST   AZIM                                   Comments....................
03C00    625.8   33.1                                  No P-arrival
01A01    680.4   32.5                                  No P-arrival

1973 JUN 24  ISC 210642.3 62.430N   2.004E  33 4.0 PEN                    2.8 MlW
         DIST   AZIM                                   Comments....................
01A01    502.5  294.4                                  No P-arrival (LF)
03C00    511.9  288.8                                  No P-arrival (LF)

1974 APR 28  BER 125254.0 68.700N  16.200E  33 4.9 PDE 4.7 PEN 4.3        3.9 MlW
         DIST   AZIM                                   Comments....................
01A01    910.8   13.7                                  Saturated, no P-arrival (LF)

1974 NOV 09  ISC 071423.9 69.635N   9.676E  33        3.8 PEN             3.2 MlW
         DIST   AZIM                                   Comments....................
03C00    937.0  355.9                                  No P-arrival (LF)
01A01    981.8  357.2                                  Noise window = 3 sec (LF)

1974 DEC 18  ISC 201215.6 67.854N  10.490E  33 4.3 ISC         4.1        3.2 MlW
         DIST   AZIM                                   Comments....................
03C00    736.3  357.0                                  Noise window < 5 sec (LF)
01A01    781.7  358.8                                  Ok (LF)

1975 JAN 20  ISC 104729.1 71.704N  14.205E  20 5.0 ISC 4.5 PEN 4.2        3.8 MlW
         DIST   AZIM                                   Comments....................
03C00   1170.8    4.8                                  Ok (LF)
01A01   1219.7    5.5                                  Ok (LF)

1975 NOV 12  ISC 000616.0 57.011N   7.173E  95 4.7 IGS 3.7 IGS            3.1 MlW
         DIST   AZIM                                   Comments....................
01A01    477.4  208.2                                  Saturated (LF)
03C00    531.9  209.0                                  Ok (LF)

1976 MAR 27  ISC 032447.5 56.734N   7.491E     3.5 NAO 2.4 UPP            2.3 MlW
         DIST   AZIM                                   Comments....................
01A01    498.0  204.7                                  No P-arrival
03C00    552.3  205.8                                  No P-arrival

[illegible]  ISC [illegible]550.1 62.835N  17.356E     3.6 MAC 2.9 UPP            2.7 MlW
         DIST   AZIM                                   Comments....................
[illegible]    356.6   58.0                                  Saturated (LF)
01A01    406.3   54.1                                  Ok (LF)

[illegible] AUG 25  [illegible] 59.554N  15.254E     3.3 PEN 2.9 PKV            [illegible].1 MlW
         DIST   AZIM                                   Comments....................
01A01    281.6  118.8                                  Ok (LF)
03C00    284.5  130.3                                  Ok (LF)

1977 APR 06  ISC 193145.1 61.734N   2.283E  10 4.4 ISC 3.9 UPP 4.6        4.2 MlW
         DIST   AZIM                                   Comments....................
[illegible]    47[illegible].5  285.9                                  Low gain, no P-arrival (LF)
03C00    488.[illegible]  280.2                                  Clipped

1977 APR 1[illegible]  ISC 002736.9 57.096N   6.108E  33 4.4 PDE 1.8 IGS            2.2 MlW
         DIST   AZIM                                   Comments....................
01A01    499.6  215.4                                  No P-arrival
03C[illegible]    [illegible]  215.[illegible]                                  No P-arrival
```

```
1977 APR 30  ISC 233241.9 68.107N  10.644E  14 4.1 ISC        3.9        3.5 MlW
       DIST   AZIM                                Comments....................
03C00   764.1  357.6                               No P-arrival (LF)
01A01   809.8  359.3                               No P-arrival (LF)

1977 NOV 07  ISC 003428.9 68.916N  28.987E   7 3.8 PEN 3.5 UPP           3.2 MlW
       DIST   AZIM                                Comments....................
03C00  1179.7   36.3                               Ok

1977 NOV 09  ISC 141442.3 63.169N   1.934E  10 4.6 PDE 4.7 IGS           3.8 MlW
       DIST   AZIM                                Comments....................
01A01   535.2  302.8                               Low gain (LF)

1977 DEC 05  ISC 034450.9 62.398N   2.172E  30 4.2 PDE 4.4 IGS           2.9 MlW
       DIST   AZIM                                Comments....................
01A01   493.2  294.3                               Ok (LF)
03C00   502.7  288.6                               Ok (LF)

1978 JAN 09  NOP 024734.6 59.860N   5.360E     3.1 MAC 2.5 NOP           2.2 MlW
       DIST   AZIM                                Comments....................
01A01   324.1  252.6                               Ok
03C00   366.8  247.5                               Ok

1978 FEB 24  ISC 110435.2 62.229N   1.806E  10 4.2 IGS 2.7 NOP           2.7 MlW
       DIST   AZIM                                Comments....................
01A01   506.6  291.7                               Ok (LF)
03C00   518.5  286.2                               Ok (LF)

1978 MAR 07  ISC 023155.2 56.764N   7.931E  33 3.0 PEN 3.5 IGS           2.1 MlW
       DIST   AZIM                                Comments....................
01A01   485.4  201.9                               Ok
03C00   539.3  203.3                               Ok

1978 MAR 16  ISC 101111.8 59.015N   1.420E  33 3.7 IGS 3.6 IGS           2.5 MlW
       DIST   AZIM                                Comments....................
01A01   566.6  253.1                               Ok
03C00   608.4  250.1                               Ok

1978 MAR 20  ISC 035739.0 62.648N   6.408E     4.3 MAC 3.2 UPP 4.1       3.1 MlW
       DIST   AZIM                                Comments....................
03C00   304.7  302.7                               Clipped
01A01   310.4  312.3                               Low gain (LF)

1978 APR 25  ISC 010236.4 58.829N   5.562E     3.0 PEN                   3.1 MlW
       DIST   AZIM                                Comments....................
01A01   373.4  235.4                               Low gain (LF)
03C00   423.8  232.8                               Saturated (LF)

1978 APR 29  ISC 211101.9 64.538N  14.554E  10 3.7 MAC 3.1 UPP 3.8       2.3 MlW
       DIST   AZIM                                Comments....................
03C00   398.5   22.2                               Ok (LF)
01A01   452.4   22.9                               Ok (LF) (3C)

1978 SEP 19  ISC 145233.9 62.338N   1.538E  10 4.7 IGS                   3.7 MlW
       DIST   AZIM                                Comments....................
01A01   523.0  292.6                               Low gain (LF)

1978 NOV 14  ISC 234018.3 66.919N  14.672E     3.0 NAO 3.3 UPP           2.5 MlW
       DIST   AZIM                                Comments....................
03C00   650.2   12.7                               Ok

1978 DEC 04  ISC 104626.8 66.797N  13.755E   7 3.1 NAO 3.3 UPP           2.5 MlW
       DIST   AZIM                                Comments....................
03C00   627.5    9.5                               Ok
01A01   678.3   10.7                               Ok

1978 DEC 09  IGS 210156.1 61.480N   3.200E     3.9 IGS                   1.8 MlW
```

```
        DIST   AZIM                                   Comments....................
01A01   419.6  283.1                                  Ok
03C00   439.7  276.8                                  Ok

1978 DEC 27  ISC 153334.5 66.785N  13.525E   7 2.9 NAO 3.1 UPP          2.5 M1W
        DIST   AZIM                                   Comments....................
03C00   624.2    8.6                                  Ok
01A01   674.8    9.9                                  Ok

1979 DEC 14  ISC 031338.7 65.058N   5.257E  10       3.6 UPP           3.0 M1W
        DIST   AZIM                                   Comments....................
03C00   524.3  326.5                                  Saturated (LF)
01A01   549.3  331.2                                  Ok (LF) (3C)

1979 DEC 23  ISC 140910.3 59.544N  18.834E           3.2 UPP           2.8 M1W
        DIST   AZIM                                   Comments....................
01A01   463.7  104.7                                  Ok (LF) (3C)

1980 MAY 27  BKH 165556.5 67.750N  15.105E     3.0 PEN 3.6 NAO          3.0 M1W
        DIST   AZIM                                   Comments....................
03C00   744.5   12.1                                  Ok (Two file-sets) (LF)
01A01   796.1   13.0                                  Ok (LF) (3C)

1980 OCT 17  BKH 185730.3 62.341N   4.767E     2.9 NAO 2.9 NAO          2.2 M1W
        DIST   AZIM                                   Comments....................
NFJ     336.9  312.5                                  Ok
01A01   365.1  299.8                                  Ok (3C)
03C00   370.4  291.8                                  Ok
SJD     373.7  327.8                                  Ok
DRA     431.0  328.6                                  Ok
SRU     431.2  308.8                                  Ok
SPG     488.0  315.8                                  Ok

1980 NOV 17  BKH 181150.0 61.796N   1.929E   2       3.0 SNN           2.4 M1W
        DIST   AZIM                                   Comments....................
NFJ     440.7  294.3                                  Ok
SJD     442.2  307.2                                  Ok
DRA     495.2  310.3                                  Ok
SRU     540.9  294.9                                  Ok
SPG     582.6  301.9                                  Ok

1981 JAN 28  BKH 144322.3 65.864N  12.913E           2.9 SNN           2.4 M1W
        DIST   AZIM                                   Comments....................
NFJ     634.1   14.0                                  Ok
SRU     652.0    6.7                                  Ok
SPG     730.1    5.7                                  Ok
SJD     736.3   15.5                                  Ok
DRA     778.4   13.0                                  Ok, local expl. in Lg window

1981 FEB 13  FRB 063909.2 58.913N  1[illegible] 974E          3.3 UPP           2.6 M1W
        DIST   AZIM                                   Comments....................
NFJ     297.6   21.4                                  Saturated
SJD     314.2  100.9                                  Saturated

1981 FEB 23  FRB 1[illegible]3518.6 70.914N   9.068E           3.7 NAO           3.1 M1W
        DIST   AZIM                                   Comments....................
03C00  1081.3  355.5                                  Ok
01A01  1125.7  356.6                                  Ok
NFJ    1174.9  359.2                                  Ok
SRU    [illegible]  [illegible]                                  Ok
[illegible]                                           Ok
SPG    [illegible]  [illegible]                                  Ok
DRA    [illegible]  [illegible]                                  Ok

1981 MAR [illegible]  FRB 044636.8 61.878N   4.992E     3.0 UPP [illegible] NAO          2.6 M1W
        DIST   AZIM                                   Comments....................
NFJ     297.4  306.1                                  Saturated
SJD     [illegible]  [illegible]                                 Saturated
```

01A01	335.6	292.6	Ok (3C)
DRA	382.6	325.6	Ok
SRU	394.8	303.5	Ok
SPG	446.8	311.7	Ok

1981 MAR 20 BKH 051101.6 68.378N 8.998E 3.2 NAO 2.6 MlW

	DIST	AZIM	Comments....................
03C00	801.5	352.9	Ok
NFJ	892.2	358.5	Ok
SJD	983.7	0.9	Ok

1981 APR 29 BKH 030849.8 61.256N 4.119E 2.9 SNN 2.4 MlW

	DIST	AZIM	Comments....................
NFJ	311.8	290.6	Ok
SJD	311.8	309.3	Ok
DRA	365.6	313.1	Ok
SRU	412.1	291 9	Ok
SPG	451.7	301.1	Ok

1981 MAY 22 BKH 034230.7 65.590N 23.290E 2.9 SNN 2.3 MlW

	DIST	AZIM	Comments....................
03C00	762.4	45.7	Ok
01A01	815.5	44.3	Ok

1981 JUN 22 BKH 043814.6 65.794N 0.194E 9 4.3 ISC 4.0 NAO 3.2 MlW

	DIST	AZIM	Comments....................
03C00	751.0	317.1	Ok (LF)
NFJ	765.4	326.0	Ok
01A01	767.3	320.5	Ok (LF) (3C)
SJD	816.7	331.9	Ok
SRU	848.4	323.5	Ok
DRA	874.1	332.2	Ok
SPG	915.8	326.3	Ok

1981 JUN 22 BKH 185318.6 59.469N 22.854E 19 3.2 NAO 2.7 MlW

	DIST	AZIM	Comments....................
SPG	653.3	83.9	Ok
SRU	654.2	90.8	Ok
03C00	661.2	102.5	Ok
01A01	681.1	97.7	Ok (3C)
NFJ	749.1	92.0	Ok
DRA	783.8	81.1	Ok
SJD	804.8	84.5	Ok

1981 JUL 15 BKH 081017.0 65.663N 0.215E 29 3.3 IGS 2.2 MlW

	DIST	AZIM	Comments....................
NFJ	754.0	325.3	Ok

1981 SEP 03 BKH 183941.1 69.577N 13.964E 4.8 ISC 4.7 UPP 4.4 4.0 MlW

	DIST	AZIM	Comments....................
03C00	934.5	6.1	Saturated(two file-sets)(LF)
01A01	984.0	7.0	Saturated (LF)
NFJ	1045.7	9.5	Saturated
SRU	1068.3	5.7	Saturated
SJD	1145.2	10.5	Saturated
SPG	1146.6	5.1	Saturated
DRA	1190.1	9.2	Saturated

1981 SEP 07 BKH 075207.5 72.651N 13.400E 4.3 ISC 3.[illegible] NAO 3.2 MlW

	DIST	AZIM	Comments....................
03C00	1273.0	3.0	Ok
01A01	1321.1	3.7	Ok

1981 NOV 11 BKH 024852.3 57.099N 13.247E 2.7 UPP 2.9 NAO 2.3 MlW

	DIST	AZIM	Comments....................
SPG	274.9	155.1	Ok
SJD	385.3	133.2	Ok
NFJ	423.0	148.1	Ok

01A01	438.7	161.0	Ok
03C00	475.4	166.5	Ok

1982 [illegible] 04 BKH 1822[illegible] 2 59.279N 5.601E — 2.8 NAO 3.8 — 2.5 MlW

	DIST	AZIM	Comments....................
SPG	326.8	271.0	Ok
01A01	342.0	241.7	Ok (LF) (3C)
03C00	390.1	238.1	Ok (LF)

1982 JAN 21 BKH 125739.1 68.245N 10.914E — 3.2 NAO — 2.8 MlW

	DIST	AZIM	Comments....................
03C00	778.9	358.5	Ok
01A01	825.1	0.1	Ok
NFJ	879.3	3.7	Ok
SJD	975.0	5.6	Ok
SPG	991.5	359.0	Ok
DRA	1022.9	4.2	Ok
EVJ	1086.8	6.5	Ok

1982 MAR 17 ISC 223309.7 62.089N 1.974E 10 — 4.2 IGS — 2.9 MlW

	DIST	AZIM	Comments....................
NFJ	449.5	298.4	Ok
SJD	458.1	310.9	Saturated
EVJ	511.4	322.3	Ok
DRA	512.3	313.5	Ok
SRU	549.0	298.3	Ok
SPG	594.4	304.8	Ok

1982 MAR 19 BKH 005205.1 65.020N 1.422W 1 — 3.6 SNN — 2.5 MlW

	DIST	AZIM	Comments....................
NFJ	663.2	324.7	Ok
SJD	713.3	331.6	Ok
SRU	747.7	321.8	Ok
DRA	770.7	332.0	Ok
EVJ	795.0	337.2	Ok, spikes in Lg window
SPG	814.0	325.0	Ok

1982 APR 19 BKH 094928.0 61.650N 4.325E — 4.0 NAO 4.1 — 3.6 MlW

	DIST	AZIM	Comments....................
NFJ	316.5	298.8	Low gain
SJD	331.0	316.7	Low gain
DRA	386.8	319.2	Low gain
EVJ	396.9	331.0	Low gain
SPG	462.3	306.6	Low gain

1982 APR 20 BKH 131929.8 59.197N 6.303E — 3.6 NAO — 3.2 MlW

	DIST	AZIM	Comments....................
EVJ	117.5	306.3	Low gain
S[illegible]	1[illegible]7.3	254.1	Low gain
DRA	[illegible]50.[illegible]	2[illegible]4.9	Low gain
[illegible]	225.[illegible]	235.[illegible]	Low gain
SPG	287.6	[illegible]68.7	Low gain

[illegible] 0.809E 20 4.4 BER 4.3 — 4.1 MlW

	DIST	AZIM	Comments....................
[illegible]	545.[illegible]	277.[illegible]	Low gain [illegible]

1982 AUG 06 BKH 074123.1 60.621N 6.336E — 3.3 NAO — 2.9 MlW

	DIST	AZIM	Comments....................
SJD	[illegible]73.[illegible]	3[illegible]4.1	Low gain
[illegible]	179.3	23[illegible]	Low gain
DRA	229.1	318.[illegible]	Low gain
EVJ	244.9	338.[illegible]	Low gain
SP[illegible]	[illegible]	[illegible]	Ok, some samples edited

[illegible] SEP 17 [illegible] 112[illegible]12.7 6[illegible].994N 15.617E 27 — 3.4 NAO — 3.0 MlW

	DIST	AZIM	Comments....................
NFJ	398.5	[illegible]6.[illegible]	No visible [illegible]

SPG	986.8	10.5	No visible P-arrival
SJD	1001.6	17.0	No visible P-arrival
DRA	1042.3	15.2	No visible P-arrival

1982 NOV 23 BKH 165836.5 60.789N 3.004E 18 3.0 NAO 2.0 MlW

	DIST	AZIM	Comments....................
SJD	340.2	296.2	Ok
NFJ	362.2	280.1	Ok
EVJ	371.8	313.5	Ok
DRA	388.7	301.5	Ok
SRU	461.4	283.7	Ok

1982 DEC 09 BKH 202108.0 66.375N 7.790E 4.4 ISC 3.2 NAO 3.4 MlW

	DIST	AZIM	Comments....................
NFJ	674.2	353.2	Ok
SRU	724.6	347.6	Ok
SJD	761.2	357.2	Ok
SPG	803.0	348.6	Ok
DRA	813.1	355.9	Ok
EVJ	868.5	359.5	Ok

1982 DEC 15 BKH 064441.3 62.283N 5.368E 3.8 NAO 4.1 3.5 MlW

	DIST	AZIM	Comments....................
NFJ	308.8	315.2	Low gain
SJD	351.1	331.3	Low gain
DRA	408.5	331.7	Low gain
EVJ	436.2	342.0	Low gain
SPG	460.3	317.7	Low gain

1982 DEC 27 BKH 181516.4 61.620N 3.837E 3 3.0 NAO 2.8 MlW

	DIST	AZIM	Comments....................
NFJ	339.1	296.5	Low gain
SJD	348.3	313.4	Low gain
DRA	403.3	316.3	Low gain
EVJ	408.7	327.6	Ok
SRU	438.9	296.5	Ok
SPG	483.2	304.7	Ok

1983 JAN 04 BKH 024033.6 58.568N 0.451W 3.2 NAO 2.3 MlW

	DIST	AZIM	Comments....................
EVJ	436.7	273.0	No P-arrival visible
SJD	480.8	260.3	No P-arrival visible
DRA	502.5	266.9	No P-arrival visible
NFJ	553.9	252.6	No P-arrival visible
SRU	636.7	259.6	No P-arrival visible

1983 FEB 24 BKH 041947.1 60.291N 1.869E 3.0 NAO 2.6 MlW

	DIST	AZIM	Comments....................
SJD	385.9	285.2	Ok
EVJ	394.4	301.4	Ok
NFJ	424.8	272.0	Ok
DRA	427.7	291.1	Ok
SRU	521.2	276.9	Ok
SPG	541.0	285.2	Ok

1983 MAR 08 BKH 184355.7 59.647N 5.387E 4.8 PDE 4.7 NAO 4.1 MlW

	DIST	AZIM	Comments....................
SJD	182.5	274.6	Low gain
EVJ	189.2	309.9	Low gain
DRA	219.4	287.6	Low gain
NFJ	246.6	252.5	Low gain
SPG	338.6	278.1	Low gain

1983 MAR 08 BKH 185206.1 59.713N 5.452E 3.0 NAO 2.3 MlW

	DIST	AZIM	Comments....................
EVJ	190.9	312.3	Low gain
NFJ	240.7	253.8	Low gain
SRU	327.3	265.7	Ok

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SPG      335.4  279.4                                   Ok

1986 JAN 19  [illegible]C 045926.2 64.673N  12.668E         3.3 NOP          2.5 MlW
             DIST   AZIM                                Comments....................
NORESS  442.7    7.0                                    Ok (3C)

1986 JAN 25  ISC 231323.6 61.710N  17.006E  10          3.3 UPP          2.3 MlW
             DIST   AZIM                                Comments....................
NORESS  313.0   67.3                                    Ok (3C)

1986 JAN 31  NOP 060016.0 65.400N  10.300E              3.0 NOP          2.3 MlW
             DIST   AZIM                                Comments....................
NORESS  523.7  353.7                                    Ok (3C)

1986 FEB 05  BER 175335.3 62.736N   4.668E  16 5.0 PDE 4.2 BER 4.8       4.7 MlW
             DIST   AZIM                                Comments....................
STF      222.5   40.9                                   Ok (problems)
NORESS  425.9  304.5                                    Ok (HF) (IP) (3C)

1986 APR 01  BER 095658.0 56.644N  12.014E  15 3.6 BER 3.3 BER           3.5 MlW
             DIST   AZIM                                Comments....................
NORESS  456.5  176.4                                    Ok (C4) (IP) (3C)

1986 APR 04  BER 224235.3 70.889N   8.873E  29 4.6 PDE 3.5 BER           3.8 MlW
             DIST   AZIM                                Comments....................
NORESS 1138.5  355.1                                    Ok (C4) (IP) (3C)

1986 JUN 15  BER 150105.9 61.670N   3.906E              3.0 BER          2.9 MlW
             DIST   AZIM                                Comments....................
NORESS  423.2  287.6                                    Ok (C4) (3C)

1986 JUL 14  UPP 111955.0 66.500N  14.500E              3.0 UPP          2.5 MlW
             DIST   AZIM                                Comments....................
NORESS  659.0   11.5                                    Ok (C4) (3C)

1986 JUL 14  BKH 135037.9 58.457N  13.753E  16 4.1 UPP 3.9 BER           4.1 MlW
             DIST   AZIM                                Comments....................
NORESS  282.8  152.8                                    Ok (HF) (IP) (3C)
ODD      438.1  108.6                                   Clipped
HYA      520.4  122.1                                   Ok
SUE      581.9  115.9                                   Ok

1986 JUL 14  BKH 144531.2 58.210N  13.872E  21 3.4 NAO 3.1 BER           2.8 MlW
             DIST   AZIM                                Comments....................
NORESS  310.7  153.8                                    Ok (C4) (3C)
BLS 14  427.7  104.9                                    Ok
ODD      456.5  111.4                                   Ok
HYA      543.3  123.9                                   Ok
SUF      603.2  117.7                                   Ok

[illegible] 15 [illegible]E 184[illegible] [illegible]N  13.174E  10 3.4 BER 3.4 NAO   3.0 MlW
             DIST   AZIM                                Comments....................
NORESS  683.5    6.0                                    Ok (C2) (3C)

1986 AUG 04  NOP 195541.0 65.800N   5.800E              3.0 NOP          2.1 MlW
             DIST   AZIM                                Comments....................
NORESS  633.3  335.5                                    Ok (C4) (3C)

1986 AUG 29  BER 073819.4 60.779N   3.961E   4          2.9 BER          2.5 MlW
             DIST   AZIM                                Comments....................
NORESS  413.1  274.0                                    Ok (C2) (3C)

1986 SEP 01  BER 221125.3 60.803N   2.929E  12 3.5 BER 3.5 BER           4.0 MlW
             DIST   AZIM                                Comments....................
01A01    432.[illegible]  272.9                         Low gain (LF)
NORESS  469.1  274.7                                    Ok (C2) (IP) (3C)

1986 [illegible] 20 [illegible]                         3.3 BER          [illegible]
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        DIST   AZIM                                 Comments...................
NORESS  273.4  104.6                                Ok (C2) (3C)
BLS 14  537.0   78.3                                Ok
ODD     539.3   84.4                                Ok
HYA     567.2   98.4                                Ok
KMY     629.1   76.9                                Ok
SUE     642.1   95.2                                Ok

1986 OCT 26  BER 113444.3 61.626N   3.918E  11 4.5 PDE 4.0 BER         4.4 MlW
        DIST   AZIM                                 Comments...................
01A01   384.1  286.1                                Low gain (LF)
NORESS  421.7  286.9                                Ok (C2) (IP) (3C)

1986 NOV 02  BER 074800.6 58.577N  13.420E  11 3.4 BER 3.4 BER         3.2 MlW
        DIST   AZIM                                 Comments...................
NORESS  262.7  155.4                                Ok (C2) (3C)
BLS 14  389.6  100.6                                Clipped, processed
ODD     414.2  108.7                                Ok
KMY     476.2   95.0                                Ok
HYA     496.9  122.3                                Ok
SUE     558.3  115.8                                Ok

1987 JAN 06  NOP 044444.0 65.700N   0.200E             3.5 NOP         2.6 MlW
        DIST   AZIM                                 Comments...................
NORESS  792.6  319.1                                Ok (3C)

1987 JAN 19  BER 040732.2 55.970N   4.871E             2.9 BER         2.2 MlW
        DIST   AZIM                                 Comments...................
NORESS  658.3  219.2                                Ok (3C)

1987 FEB 04  BER 120244.0 61.586N   4.586E  17 3.7 NB2 3.3 BER         3.1 MlW
        DIST   AZIM                                 Comments...................
SUE      59.7  351.0                                Clipped, processed
HYA      97.6  299.4                                Clipped, processed
ODD     214.7  329.0                                Ok
KMY     267.0  352.4                                Ok
BLS 14  273.9  334.2                                Clipped, processed
NORESS  386.1  287.2                                Ok (3C)
NSS     496.6  232.0                                Ok

1987 MAR 01  BER 064208.1 57.285N   6.821E  10         3.2 BER         3.0 MlW
        DIST   AZIM                                 Comments...................
KMY     233.7  156.0                                Ok
ODD     297.0  178.2                                Ok
BYA     433.9  174.9                                Ok
SUE     436.4  163.4                                Ok
NORESS  470.1  217.3                                Ok (3C)
MOL     590.2  184.3                                Ok

1987 APR 04  NOR 072914.3 67.382N   7.549E  30         3.1 BER         3.0 MlW
        DIST   AZIM                                 Comments...................
LOF     265.9  254.5                                Ok
MOR     341.8  295.2                                Clipped, processed
NSS     375.9  329.7                                Saturated
MOL     536.5    0.0                                Ok
HYA     696.1    4.8                                No P-arrival
SUE     717.8    9.6                                Noise window < 1 sec
NORESS  765.8  347.0                                Ok (3C)
ODD     829.6    2.6                                Ok
KMY     917.8    6.2                                Ok, long period pulse in Lg

1987 APR 19  NOR 123953.2 67.873N  19.624E   1 3.2 BER 3.2 BER         3.0 MlW
        DIST   AZIM                                 Comments...................
KTK     195.1  231.1                                Ok
MOR     279.0   47.0                                Clipped, processed
NSS     507.1   39.3                                Ok, 1 sec datagap in Lg win.
MOL     815.1   38.3                                Ok
NORESS  885.1   22.6                                Ok (3C)
```

1987 APR 19 NOR 221525.5 57.369N 8.023E			2.9 BER 2.8 MlW
	DIST	AZIM	Comments....................
KMY	262.0	140.4	Saturated, no P-arrival
ODD	298.1	164.1	No P-arrival
NORESS	425.7	209.8	Ok (3C)
HYA	435.7	165.3	Ok
SUE	451.0	154.2	Ok
MOL	580.1	177.2	Ok
NSS	825.8	196.7	Ok

1987 MAY 21 HEL 163141.0 67.1 N 20.6 E 0			2.1 HEL M 2.2 MlW
	DIST	AZIM	Comments....................
NOR	275.1	66.9	Ok
LOF	321.9	107.6	Ok

1987 MAY 25 NOR 023525.6 61.783N 4.748E			3.1 BER 2.7 MlW
	DIST	AZIM	Comments....................
NORESS	382.6	290.7	Ok (3C)

1987 MAY 27 NOP 024801.0 67.700N 22.700E			3.0 NOP 2.6 MlW
	DIST	AZIM	Comments....................
NORESS	943.8	30.0	Ok

1987 JUN 14 NOR 032011.7 69.422N 14.173E 6			2.9 BER 2.3 MlW
	DIST	AZIM	Comments....................
LOF	146.3	10.0	Ok
TRO	187.1	265.0	Ok
NSS	553.8	9.0	Ok

1987 JUN 16 NOR 114716.8 66.434N 15.169E			3.0 BER 2.1 MlW
	DIST	AZIM	Comments....................
MOR	28.3	39.2	Clipped, processed
LOF	202.2	158.7	Ok
NSS	258.8	33.5	Ok

1987 SEP 04 NOR 013149.4 69.525N 13.427E 15			2.9 BER 2.0 MlW
	DIST	AZIM	Comments....................
LOF	155.4	358.6	Ok
TRO	214.6	269.4	Ok
KTK	391.5	283.0	Ok
NSS	560.5	5.8	Ok
MOL	819.2	16.3	Ok

1987 SEP 04 NOR 083820.4 61.363N 3.002E 15			2.9 BER 3.2 MlW
	DIST	AZIM	Comments....................
STF	64.6	78.8	Clipped, procesed
SUE	100.5	290.6	Clipped, processed
HYA	172.3	278.7	Clipped, processed
ODD	254.8	309.7	Saturated
KMY	269.9	333.6	Saturated (Ok)
MOL	273.7	242.6	Ok
BLS 14	304.6	317.8	Saturated
01A0	[illegible]	[illegible]	Low gain (LF)
03C0	450.[illegible]	275.1	Ok (LF)
NORESS	466.3	282.[illegible]	Ok (3C)
NSS	575.2	236.2	Ok

1987 SEP 05 NOR 011722.9 65.656N 12.349E 15			3.4 BER 2.5 MlW
	DIST	AZIM	Comments....................
NSS	126.7	8.0	Clipped processed
LOF	280.9	191.1	Ok
MOL	415.8	32.1	Ok
NORESS	550.0	3.9	Ok (3C)
KTK	538.1	226.5	Ok

1987 SEP 05 HEL 124958.6 65.19 N 0.07 E 10			3.0 HEL 3.2 MlW
	DIST	AZIM	Comments....................

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MOL     468.9  311.8                          Ok
NSS     568.1  282.8                          Ok
LOF     677.5  247.4                          Ok
NORESS  763.1  315.5                          Ok (3C)
KTK    1084.5  258.0                          Ok

1987 SEP 08  NOR 094941.0 66.569N  14.500E  15      3.2 BER          2.3 MlW
        DIST   AZIM                           Comments...................
LOF     179.3  166.0                          Ok
NSS     255.6   26.1                          Ok
KTK     457.7  237.6                          Ok
MOL     556.0   33.7                          Ok
NORESS  666.5   11.4                          Ok, local event in Lg window

1987 SEP 11  NOR 163043.5 66.895N  21.073E  15      3.2 BER      M   1.9 MlW
        DIST   AZIM                           Comments...................
KTK     252.8  202.0                          Ok
TRO     318.0  162.8                          Ok
LOF     350.3  109.7                          Ok
NSS     493.6   53.7                          Ok

1987 SEP 17  HEL 163552.0 67.1  N  20.6  E   0      2.1 HEL      M   2.1 MlW
        DIST   AZIM                           Comments...................
KTK     239.8  208.5                          Ok
TRO     290.8  165.5                          Ok
LOF     321.9  107.6                          Ok

1987 SEP 20  NOR 063745.7 67.637N  15.042E  15      2.9 BER          1.9 MlW
        DIST   AZIM                           Comments...................
LOF      84.4  130.2                          Ok
MOR     156.5    4.3                          Ok
TRO     272.9  217.2                          Ok

1987 OCT 04  BER 022509.9 58.793N   1.621E  16 3.4 BGS 2.6 BER       2.5 MlW
        DIST   AZIM                           Comments...................
KMY     213.5  258.9                          Ok
BLS 14  305.7  259.7                          Ok (wrong gain)
SUE     307.3  216.2                          Ok
ODD     314.4  248.0                          Ok
HYA     367.1  226.0                          Ok
NORESS  597.3  253.1                          Ok (3C)

1987 OCT 19  NOR 053410.6 59.747N   6.631E   6      3.0 BER          2.8 MlW
        DIST   AZIM                           Comments...................
MOL     318.4  189.3                          Saturated

1987 OCT 31  NOR 100914.9 61.105N   4.294E  19 4.2 PDE 3.3 BER       3.6 MlW
        DIST   AZIM                           Comments...................
STF     134.3   96.1                          Ok
KMY     217.4  346.3                          Clipped, processed
01A01   358.0  277.5                          Low gain (LF)
NORESS  395.1  279.1                          Ok (3C)
MOR     770.3  227.0                          Ok
ARCESS 1351.0  236.5                          Ok (3C)

1987 NOV 01  NOR 203935.6 65.076N  11.807E  10 3.3 BER 3.3 BER       3.1 MlW
        DIST   AZIM                           Comments...................
MOL     349.2   35.0                          Ok
LOF     349.2  193.4                          Ok (3C)
NORESS  484.1    1.5                          Ok (3C)
TRO     592.5  214.4                          Ok
KTK     661.7  234.0                          Ok
ARCESS  768.7  236.3                          Ok (3C)

1987 NOV 03  NOR 223515.3 68.324N  15.542E  10      3.0 BER          2.3 MlW
        DIST   AZIM                           Comments...................
LOF      86.3   74.7                          Clipped, processed
TRO     199.2  224.5                          Ok
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KTK     321.5  259.8                              Ok
ARCESS  421.6  256.0                              Ok (3C)

1987 NOV 12  NOP 055256.0 68.200N  26.600E          2.9 NOP           2.4 MlW
        DIST   AZIM                               Comments...................
ARCESS  155.3  163.0                              Ok (3C)

1987 DEC 23  BKH 125932.2 69.4  N  30.8  E   0      3.1 HEL       M   3.1 MlW
        DIST   AZIM                               Comments...................
ARCESS  207.8   91.7                              Ok, Rg phase present (3C)

1987 DEC 26  BER 165742.2 59.788N   6.359E    3.3 BER 2.6 BER         2.9 MlW
        DIST   AZIM                               Comments...................
KMY      89.9   44.0                              Saturated
HYA     153.8  176.4                              Ok
SUE     166.6  147.4                              Ok
01A01   276.4  246.8                              Low gain (LF)
NORESS  305.6  252.1                              Ok (3C)
03C00   322.4  241.6                              Ok (LF)

1988 JAN 03  NOR 203653.3 67.590N  10.399E  10      3.1 BER           2.0 MlW
        DIST   AZIM                               Comments...................
LOF     144.7  246.8                              Ok
NSS     348.4  349.0                              Ok

1988 JAN 12  HEL 153304.0 67.1  N  20.6  E   0      3.0 BER       M   1.6 MlW
        DIST   AZIM                               Comments...................
KTK     239.8  208.5                              Ok
TRO     290.8  165.5                              Ok
LOF     321.9  107.6                              Ok
NSS     487.1   50.2                              Ok

1988 JAN 19  BER 070209.2 61.074N   4.306E  12      2.8 BER           2.3 MlW
        DIST   AZIM                               Comments...................
SUE      24.6  274.6                              Clipped, processed
HYA     101.9  265.0                              Ok
ODD     180.3  315.0                              Ok
KMY     213.9  346.3                              Ok
BLS 14  233.9  324.4                              Ok

1988 JAN 23  NOR 062135.7 65.653N   2.108E  10 4.9 PDE 3.1 BER        3.3 MlW
        DIST   AZIM                               Comments...................
MOL     433.8  324.8                              Ok
SUE     529.1  346.6                              Ok
HYA     539.8  339.6                              Ok
LOF     570.3  246.4                              Ok (3C)
ODD     676.5  341.9                              Ok
KMY     735.8  348.7                              Ok
TRO     836.8  246.1                              Ok
KTK     976.[illegible]  257.6                              Ok
NORESS  723.8  323.2                              Ok
ARCESS [illegible]77.1  257.6                              Ok (3C)

1988 JAN 24  NOR 111045.3 67.074N  13.447E  10 2.3 BER 3.2 BER        2.1 MlW
        DIST   AZIM                               Comments...................
MOL     [illegible]10.0  [illegible]28.5                              Saturated
LOF     118.0  181.6                              Ok (3C)
KTK     461.5  246.7                              Ok
ARCESS  567.0  246.8                              Ok
MOL     574.5   26.5                              Ok, noisy
NORESS  712.8    6.7                              Ok

1988 JAN 29  NOR 125444.6 69.125N  [illegible].385E  10 3.1 BER 3.2 BER     M   2.7 MlW
        DIST   AZIM                               Comments...................
ARCESS  1[illegible]8.[illegible]  102.8                              Ok, Rg phase present (3C)
TRO     434.0   92.3                              Ok
LOF     672.7   73.0                              Ok (3C)
NSS     933.[illegible]   48.9                              Ok
```

	DIST	AZIM	Comments
NORESS	1266.1	34.8	Ok

1988 JAN 31 NOR 185142.1 68.086N 9.242E 10 4.3 PDE 3.5 BER 3.7 MlW

	DIST	AZIM	Comments..................
NSS	414.8	344.1	Clipped, processed
TRO	425.9	250.7	Clipped, processed
MOL	620.0	6.5	Ok
03C00	767.8	353.2	Ok (LF)
HYA	785.0	9.4	Ok
01A01	811.2	355.1	Low gain (LF)
SUE	812.1	13.3	Ok
NORESS	826.9	353.3	Ok (3C)
ODD	915.5	6.8	Ok
BLS 14	976.5	5.9	Ok
KMY	1008.3	9.5	Ok

1988 FEB 01 HEL 124049.4 66.44 N 14.71 E 0 3.3 BER 2.4 MlW

	DIST	AZIM	Comments..................
TRO	397.1	208.3	Ok
KTK	460.2	235.5	Ok
MOL	551.2	35.4	Ok
ARCESS	567.3	237.7	Ok (3C)
NORESS	654.9	12.5	Ok (3C)

1988 FEB 18 BER 215037.5 60.705N 3.254E 11 2.7 BER 2.3 MlW

	DIST	AZIM	Comments..................
SUE	90.8	245.1	Ok
HYA	167.1	253.4	Ok
KMY	200.2	327.1	Ok
ODD	206.5	295.5	Ok
BLS 14	247.1	307.9	Ok

1988 FEB 24 NOR 175716.1 66.431N 14.624E 10 3.2 BER 2.2 MlW

	DIST	*AZIM*	*Comments..................*
LOF	195.5	165.5	Ok
NSS	245.0	29.0	Ok
TRO	399.6	208.7	Ok
KTK	463.7	235.8	Ok
MOL	547.9	35.2	Ok
ARCESS	570.8	237.9	Ok (3C)
NORESS	653.0	12.2	Ok (3C)

1988 FEB 29 NOR 184947.9 67.295N 20.492E 10 3.0 BER M 2.2 MlW

	DIST	AZIM	Comments..................
ARCESS	323.6	221.8	Ok (3C)
NORESS	850.5	26.9	Ok, noisy

1988 MAR 02 NOR 123838.0 69.238N 29.598E 10 3.1 BER M 2.4 MlW

	DIST	AZIM	Comments..................
ARCESS	164.2	99.7	Ok, Rg phase present (3C)

1988 MAR 03 HEL 173752.4 72.56 N 13.52 E 0 3.1 BER 2.5 MlW

	DIST	AZIM	Comments..................
ARCESS	548.7	313.4	Ok (3C)

1988 MAR 05 BKH 95517.6 67.381N 34.116E 0 3.3 BER M 3.2 MlW

	DIST	AZIM	Comments..................
ARCESS	426.4	120.2	Ok (3C)

1988 MAR 06 BER 031132.0 60.007N 5.875E 1 2.0 BER 1.5 MlW

	DIST	AZIM	Comments..................
ODD	44.7	278.5	Ok
BLS 14	87.2	322.5	Ok
KMY	95.4	21.5	Ok
HYA	130.3	187.7	Ok
SUE	132.0	151.9	Ok

1988 MAR 09 BER 170715.3 60.940N 4.011E 2 2.7 BER 2.2 MlW

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        DIST   AZIM                                   Comments....................
SUE       42.6  252.5                                 Ok, S energy in P window
HYA      120.2  258.9                                 Ok
ODD      183.1  308.2                                 Ok
KMY      204.5  340.9                                 Ok
BLS 14   232.9  319.1                                 Ok

1988 MAR 17  BER 185807.0 59.678N   5.516E  10        3.2 BER          2.7 MlW
        DIST   AZIM                                   Comments....................
KMY       54.1   16 3                                 Clipped, processed
ODD       71.3  245.4                                 Clipped, processed
SUE      159.2  164.5                                 Saturated
HYA      169.9  192.9                                 Ok
01A01    324.4  248.7                                 Low gain (LF)
NORESS   354.1  253.2                                 No P-arrival (3C)
03C00    369.1  244.0                                 Ok (LF)

1988 MAR 21  BER 201947.9 61.313N   4.431E  10        3.0 BER          2.7 MlW
        DIST   AZIM                                   Comments....................
HYA       95.7  280.6                                 Clipped, processed
ODD      195.0  322.1                                 Ok
KMY      238.4  349.4                                 Ok
BLS 14   251.8  329.3                                 Ok
NORESS   389.6  282.6                                 Ok (3C)

1988 MAR 31  BER 025607.8 56.533N   3.383E  15        [illegible].8 BER       4  2.4 MlW
        DIST   AZIM                                   Comments....................
KMY      318.2  201.1                                 Ok
BLS 14   377.8  214.1                                 Ok
ODD      426.6  208.3                                 Ok
SUE      510.2  189.6                                 Ok

1988 APR 24  HEL 211251.0 67.88 N  10.15 E  15        3.6 HEL          2.8 MlW
        DIST   AZIM                                   Comments....................
ARCESS   647.4  260.7                                 Ok (3C)
NORESS   799.4  355.8                                 Ok (3C)

1988 APR 25  PDE 200933.0 78.560N   6.105E  10 4.8 PDE        4.4      3.6 MlW
        DIST   AZIM                                   Comments....................
ARCESS 1157.0  338.5                                  Ok (3C)

1988 MAY 03  BER 063413.3 57.313N   6.775E  15 2.0 BER 2.6 BER          2.0 MlW
        DIST   AZIM                                   Comments....................
KMY      229.7  156.4                                 Ok
BLS 14   231.4  180.8                                 Ok
ODD      293.8  178.7                                 Ok
HYA      430.5  175.3                                 Ok

1988 MAY 12  BER 101141.9 61.008N   3.581E  15        2.3 BER          1.4 MlW
        DIST   AZIM                                   Comments....................
SUE       64.0  265.6                                 Ok
BER      118.4  306.8                                 Ok
HYA      141.7  264.0                                 Ok
KMY      220.[illegible]  335.9                                 Ok
BLS 14   254.7  316.4                                 Ok

1988 MAY 13  NOP 003731.0 66.800N  29.600E            3.1 NOP          2.8 MlW
        DIST   AZIM                                   Comments....................
ARCESS   349.1  149.0                                 Ok (3C)
[illegible]TK      363.3  [illegible]29.7                                 Saturated
[illegible]RO      [illegible]42.3   [illegible]0.5                                 Ok
NORESS [illegible]11.7   [illegible]4.5                                  Ok

1988 MAY 16  BER 235023.1 67.568N  21.380E  15 3.4 BER 3.3 BER          2.9 MlW
        DIST   AZIM                                   Comments....................
ARCESS   276.5  219.4                                 Ok (3C)
NORESS   897.4   27.8                                 Ok (3C)
```

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1988 MAY 17  BER 002326.7 65.108N   6.003E  15 2.7 BER 3.1 BER          2.7 MlW
        DIST   AZIM                            Comments...................
MOL     292.9  345.6                           Ok
LOF     473.5  228.2                           Ok (3C)
NORESS  562.4  332.4                           Ok (3C)
ARCESS  967.7  248.8                           Ok

1988 MAY 23  BER 035528.0 57.466N   6.779E  15 2.9 BER 3.0 BER          2.8 MlW
        DIST   AZIM                            Comments...................
NORESS  454.8  218.9                           Ok (3C)

1988 MAY 28  HEL 145600.6 57.94 N   7.18 E  15     2.8 HEL              2.7 MlW
        DIST   AZIM                            Comments...................
ODD     222.0  171.5                           Ok
BER     292.5  157.9                           Saturated
HYA     363.8  170.7                           Ok
SUE     373.3  157.4                           Ok
01A01   385.9  214.7                           Low gain (LF)
NORESS  398.0  220.5                           Ok (3C)
03C00   440.4  214.7                           Ok (LF)

1988 JUN 02  BER 113555.6 62.057N   2.479E  15 3.0 BER 2.9 BER          3.0 MlW
        DIST   AZIM                            Comments...................
SUE     164.7  313.6                           Clipped, processed
HYA     220.4  298.4                           Ok
MOL     269.0  260.0                           Ok
ODD     326.2  317.8                           Ok
KMY     351.3  335.7                           Ok
BLS 14  380.1  323.3                           Ok
01A01   468.0  290.4                           Low gain (LF)
03C00   481.2  284.5                           Ok (LF)
NORESS  505.7  290.9                           Ok (3C)

1988 JUN 03  BER 060505.0 59.747N   5.568E  15 1.9 BER 2.4 BER          1.9 MlW
        DIST   AZIM                            Comments...................
KMY      62.3   16.8                           Ok
ODD      65.6  250.3                           Ok
BLS 14   81.5  299.7                           Ok
SUE     152.6  162.7                           Ok, airgun noise
HYA     161.7  192.4                           Ok

1988 JUN 08  BER 020331.6 66.560N  15.987E  15 2.6 BER 3.1 BER          2.1 MlW
        DIST   AZIM                            Comments...................
LOF     204.8  147.7                           Ok (3C)
TRO     363.9  201.0                           Ok
NORESS  685.3   16.8                           Ok (3C)

1988 JUN 27  BKH  75525.5 58.203N  11.022E   2     3.0 BER              2.3 MlW
        DIST   AZIM                            Comments...................
NORESS  283.6  186.2                           Ok (3C)
ODD     315.8  125.2                           Ok
HYA     427.7  138.4                           Ok
SUE     474.9  129.3                           Ok

1988 JUL 23  BER 070439.2 59.517N   5.608E  15 2.0 BER 2.4 BER          1.9 MlW
        DIST   AZIM                            Comments...................
KMY      39.7   31.0                           Ok
BLS 14   70.6  282.1                           Ok
ODD      76.7  231.5                           Ok
SUE     177.9  164.4                           Ok
HYA     186.5  190.1                           Ok

1988 JUL 30  BER 024142.2 61.218N   5.289E  15     2.3 BER              1.1 MlW
        DIST   AZIM                            Comments...................
SUE      33.6   57.5                           Ok
HYA      48.6  277.2                           Ok
ODD     160.2  332.5                           Ok
BLS 14  220.7  338.0                           Ok
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1988 JUL 31  BER 090808.4 62.045N   2.415E  15 2.7 BER 2.8 BER           3.1 MlW
        DIST   AZIM                                 Comments...................
SUE     166.4  312.5                                Clipped, processed
HYA     222.8  297.7                                Ok
ODD     327.7  317.3                                Ok
KMY     351.6  335.1                                Ok
BLS 14  381.3  322.8                                Ok, clipped in P-window

1988 AUG 06  BER 035259.5 59.957N   6.319E   3 1.1 BER 2.2 BER           0.8 MlW
        DIST   AZIM                                 Comments...................
ODD      19.5  272.4                                Ok
BLS 14   69.4  335.8                                Ok
KMY     102.7   35.7                                Ok
HYA     134.9  176.9                                Ok

1988 AUG 08  BER 195934.0 63.672N   2.386E  11 4.8 NAO 4.0 BER 5.3    5  5.0 MlW
        DIST   AZIM                                 Comments...................
01A01   541.9  309.2                                Low gain (LF)
NORESS  577.3  308.5                                Ok (HF) (IP) (3C)
TRO     983.0  235.6                                Saturated
ARCESS 1204.4  248.5                                Ok (3C)

1988 AUG 21  BER 145201.3 66.634N  12.477E   8         3.3 BER           2.3 MlW
        DIST   AZIM                                 Comments...................
LOF     173.0  195.5                                Ok (3C)
NSS     235.7    5.5                                Ok
TRO     428.3  221.8                                Ok
MOL     510.5   25.3                                Ok
ARCESS  630.2  245.4                                Ok (3C)
NORESS  659.2    3.6                                Ok (3C)

1988 SEP 01  BER 172838.4 66.970N  21.213E     2.4 BER 3.0 BER      M    2.1 MlW
        DIST   AZIM                                 Comments...................
KTK     242.8  201.3                                Ok
MOR     297.0   71.1                                Ok
TRO     311.6  161.3                                Ok
ARCESS  336.6  213.8                                Ok (3C)
LOF     352.2  108.0                                Ok (3C)
NSS     502.9   53.2                                Ok

1988 SEP 02  BER 181402.1 66.916N  20.808E  37 1.9 BER 3.0 BER      M    1.8 MlW
        DIST   AZIM                                 Comments...................
KTK     254.8  204.7                                Ok
MOR     278.4   71.5                                Ok
TRO     312.8  164.7                                Ok
ARCESS  350.8  215.9                                Ok (3C)

1988 SEP 17  BER 094947.4 61.420N   1.571E  18 2.8 BER 3.1 BER           2.9 MlW
        DIST   AZIM                                 Comments...................
SUE     176.0  284.7                                Ok
HYA     249.0  278.5                                Ok
KMY     319.0  322.0                                Ok
ODD     322.9  302.7                                Ok
MOL     338.3  250.4                                Ok
BLS 14  367.4  310.2                                Ok
NORESS  543.0  282.4                                Ok (3C)
LOF     936.5  222.8                                Ok
KTK    1308.3  240.4                                Ok

1988 SEP 28  BER 0916[illegible]                        BER 3.4 BER           [illegible]
        DIST   AZIM                                 Comments...................
TRO     370.7  251.9                                Ok
MOL     660.2   10.0                                Ok
NORESS  854.0  356.7                                Ok

1988 OCT 20  BKH 214349.6 60.070N   6.420E     3.6 BER 3.8 NRS           3.4 MlW
        DIST   AZIM                                 Comments...................
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01A01    260.4  252.6                                     Low gain (LF)
NORESS   291.8  257.5                                     Ok (3C)
MOR      804.6  215.3                                     Ok
ARCESS 1379.5   229.7                                     Ok

1988 OCT 27  BKH 142216.7 66.892N   8.880E  25              3.8 HEL            3.4 MlW
         DIST   AZIM                                      Comments...................
TRO      514.8  238.4                                     Ok
HYA      651.6   10.4                                     Ok
SUE      680.7   15.4                                     Ok
NORESS   698.6  350.4                                     Ok (3C)
BER      745.9   12.1                                     Ok
ARCESS   746.3  254.7                                     Ok (3C)
ODD      786.0    7.2                                     Ok
BLS 14   842.5    6.1                                     Ok

1988 OCT 27  BKH 224728.4 66.957N   8.824E  25              3.0 HEL            2.3 MlW
         DIST   AZIM                                      Comments...................
LOF      239.4  239.0                                     Ok (3C)
NSS      306.4  333.4                                     Ok
MOL      492.9    6.5                                     Ok
NORESS   706.2  350.3                                     Ok
ARCESS   744.8  255.3                                     Ok

1988 NOV 09  HEL 183252.0 67.1  N  20.6  E   0              2.3 HEL        M   2.3 MlW
         DIST   AZIM                                      Comments...................
KTK      239.8  208.5                                     Ok
ARCESS   338.5  219.0                                     Ok (3C)
NORESS   835.5   28.1                                     Ok

1988 NOV 29  BER 230342.0 67.958N  20.661E                  3.0 BER            1.7 MlW
         DIST   AZIM                                      Comments...................
KTK      157.8  223.1                                     Ok
TRO      199.5  158.7                                     Ok
ARCESS   263.3  230.4                                     Ok (3C)
LOF      298.4   90.4                                     Ok (3C)
NSS      545.8   41.7                                     Ok

1988 DEC 06  HEL 162141.8 77.01 N  26.14 E  10              4.0 BER            3.7 MlW
         DIST   AZIM                                      Comments...................
ARCESS   834.5    1.1                                     Ok (3C)
TRO      853.6   12.2                                     Ok
KTK      897.4    4.7                                     Ok
LOF     1071.4   17.1                                     Ok
MOR     1261.4   13.1                                     Ok
NSS     1477.0   13.9                                     Ok

1988 DEC  7  BER 182854.3 67.039N  21.480E   4 3.2 BER 2.0 BER        M   1.5 MlW
         DIST   AZIM                                      Comments...................
KTK      231.9  199.3                                     Ok
TRO      307.8  158.8                                     Ok
MOR      310.1   70.2                                     Ok
ARCESS   324.1  212.7                                     Ok
NSS      516.8   53.0                                     Ok

1988 DEC 15  BER 131038.7 57.816N  11.495E   0 3.1 BER 0.0                 1.9 MlW
         DIST   AZIM                                      Comments...................
NORESS   325.2  180.5                                     Ok (3C)
ODD      366.0  128.4                                     Ok
KMY      395.8  110.4                                     Ok
HYA      479.0  138.8                                     Ok, much long-period noise
MOL      572.9  155.8                                     Ok

1988 DEC 15  BER 183003.0 66.833N  21.486E   2 3.2 BER 0.0            M   1.8 MlW
         DIST   AZIM                                      Comments...................
KTK      253.8  197.6                                     Ok
TRO      329.7  160.1                                     Ok
ARCESS   344.3  210.8                                     Ok (3C)
```

NSS	506.6	55.3	Ok
MOL	814.4	48.3	Ok, noisy (At quantum level)

1988 DEC 23 HEL 81843.0 67.6 N 34.2 E 0 3.4 BER M 3.3 MlW

	DIST	AZIM	Comments....................
KTK	478.3	104.0	Ok

1988 DEC 24 BER 213052.3 68.575N 12.787E 7 3.0 BER 2.1 BER 2.0 MlW

	DIST	AZIM	Comments..... ....
TRO	271.4	247.1	Ok
MOL	274.1	342.9	Ok
KTK	424.3	268.3	Ok
ARCESS	517.8	264.1	Ok, noisy
MOI	711.3	17.5	Ok

1988 DEC 31 BER 140059.0 69.903N 31.254E 13 3.7 BER 2.8 BER M 2.8 MlW

	DIST	AZIM	Comments....................
ARCESS	226.1	76.9	Ok, Rg phase present (3C)
KTK	329.3	68.7	Ok
TRO	476.1	80.6	Ok
MOL	1329.3	42.0	Ok, noisy (at quantum level)
NORESS	1362.1	33.3	Ok

1989 JAN 2 BER 182932.4 67.093N 21.012E 0 3.2 BER 0.0 M 1.9 MlW

	DIST	AZIM	Comments....................
KTK	233.2	204.5	Ok
MOR	292.0	68.1	Ok
TRO	296.0	162.2	Ok
ARCESS	329.3	216.3	Ok (3C)

1989 JAN 6 BER 120731.7 67.923N 34.447E 15 3.7 BER 0.0 M 3.1 MlW

	DIST	AZIM	Comments....................
ARCESS	403.8	112.2	Ok (3C)
KTK	474.4	99.5	Ok
TRO	653.5	99.6	Ok
MOR	872.0	68.7	Ok

1989 JAN 10 BER 110530.4 60.825N 4.849E 1 4.5 BER 0.0 1.3 MlW

	DIST	AZIM	Comments ....
NORESS	364.6	274.5	Ok

1989 JAN 13 BER 41824.6 62.852N 6.262E 0 3.3 BER 0.0 2.7 MlW

	DIST	AZIM	Comments....................
SUF	215.0	20.8	Ok
ODD	324.1	356.3	Ok
NSS	338.5	239.0	Ok
NORESS	364.8	312.6	Ok (3C)
BLS 14	387.0	355.7	Ok
KMY	409.3	7.3	Ok
MOR	555.1	231.1	Ok

1989 JAN 15 BER 10[illegible] 3.2 BER 0.0 M 2.0 MlW

	DIST	AZIM	Comments....................
KTK	255.3	197.3	Ok
MOR	300.4	74.8	Ok
TRO	331.	160.	Ok
ARCESS	345.6	210.6	Ok (3C)
NSS	506.6	55.6	Ok

19[illegible] JAN 16 BER 214[illegible] BER 0.0 [illegible]

	DIST	AZIM	Comments
TRO	637.	28[illegible]	Ok
MOR	687.5	317.5	Ok
NSS	768.6	332.0	Ok

1989 JAN 20 BER 93346.2 57.618N 9.479E 1[illegible] 3.1 BER 0.0 4.0 MlW

	DIST	AZIM	Comments.. .....
01A01	384.7	202.0	Low gain (1?)

```
NORESS  388.8  208.1                            Ok (3C)
HYA     416.1  160.8                            Ok
SUE     437.5  149.5                            Ok
ARCESS 1562.7  220.4                            Ok (3C)

1989 JAN 20  BER 182953.1 66.969N  21.640E   2 3.2 BER 0.0          M   2.0 MlW
        DIST   AZIM                             Comments...................
KTK     237.3  197.1                            Ok
MOR     315.2   71.9                            Ok
TRO     317.5  158.1                            Ok
ARCESS  327.7  211.0                            Ok (3C)
LOF     369.2  106.8                            Ok
NSS     519.4   54.1                            No P-arrival

1989 JAN 23  BER 140628.5 61.952N   4.404E  29 4.9 BER 0.0     5.1       4.8 MlW
        DIST   AZIM                             Comments...................
NORESS  405.1  292.7                            Ok (HF) (IP) (3C)
LOF     810.2  216.1                            Ok (3C)
TRO    1078.5  224.6                            Ok
KTK    1166.3  236.8                            Ok
ARCESS 1273.3  238.9                            Ok (3C)

1989 JAN 29  BER 163822.2 59.651N   6.016E   0 4.2 BER 4.6 NAO           4.4 MlW
        DIST   AZIM                             Comments...................
OSG     198.6  117.0                            Saturated
01A01   300.6  245.9                            Low gain (LF)
NORESS  329.3  250.9                            Ok (HF) (IP) (3C)
NSS     625.9  212.4                            Ok
ARCESS 1431.1  229.4                            Ok (3C)

1989 FEB 14  BER 204422.3 61.050N   3.943E  21 2.8 BER 3.0 BER           3.0 MlW
        DIST   AZIM                             Comments...................
01A01   376.9  276.5                            Low gain (LF)
03C00   402.8  269.9                            Ok (LF)
NORESS  413.8  278.2                            Ok (3C)

1989 FEB 21  BER  254 3.1 65.336N  29.310E   5 4.2 BER 3.2 BER           2.9 MlW
        DIST   AZIM                             Comments...................
KTK     486.5  144.5                            No P-arrival
ARCESS  495.6  159.0                            Ok (3C)
TRO     651.6  132.3                            Ok
LOF     760.0  106.7                            Ok (3C)
NORESS 1030.2   52.6                            Ok (3C)

1989 FEB 26  HEL  33349.0 67.6  N  34.0  E   0         3.1 HEL      M   3.1 MlW
        DIST   AZIM                             Comments...................
ARCESS  407.7  117.9                            Ok (3C)
KTK     470.6  104.5                            Ok
TRO     652.1  103.2                            Ok
LOF     859.4   84.4                            Ok (3C)
NORESS 1321.8   45.2                            Ok (3C)

1989 FEB 28  BER 183648.9 66.889N  21.571E   0 3.4 BER 2.2 BER      M   2.1 MlW
        DIST   AZIM                             Comments...................
KTK     246.7  197.2                            Ok
TRO     324.9  159.1                            Ok
ARCESS  337.0  210.8                            Ok (3C)

1989 MAR  3  BER 1049 3.2 60.632N   6.321E   4 3.2 BER 0.0               1.1 MlW
        DIST   AZIM                             Comments...................
HYA      59.9  173.0                            Ok
ODD      78.4  346.0                            Ok
SUE      97.1  118.5                            Ok
BLS 14  141.2  348.7                            Ok
KMY     169.2   20.3                            Ok

1989 MAR 11  BER 1738 2.8 67.187N  13.408E  21 3.0 BER 0.0               1.8 MlW
        DIST   AZIM                             Comments...................
```

LOF 105.5 182.7 Ok (3C)
NSS 303.4 11.9 Ok
TRO 354.5 222.3 Ok, noisy
KTK 456.4 248.2 Ok
ARCESS 561.4 248.0 Ok, noisy
MOL 584.3 25.7 Ok, noisy

1989 MAR 26 BER 65042.8 66.541N 13.440E 18 3.1 BER 1.8 BER 1.9 MlW
DIST AZIM Comments....................
LOF 177.5 181.2 Ok (3C)
TRO 413.5 216.1 Ok, noisy
KTK 496.1 240.9 Ok
MOL 524.7 29.9 Ok
ARCESS 602.9 242.2 Ok

1989 MAR 26 BKH 92910.0 72.950N 5.351E 8 4.2 HEL 2.9 MlW
DIST AZIM Comments....................
TRO 608.8 313.6 Ok
LOF 616.4 334.3 Ok (3C)
KTK 780.6 312.3 Ok
ARCESS 812.4 307.1 Ok (3C)

1989 MAR 26 BER 105938.9 72.430N 9.219E 1 3.3 BER 0.0 2.1 MlW
DIST AZIM Comments....................
TRO 469.7 316.1 Ok
LOF 505.9 343.3 Ok (3C)
KTK 639.8 312.9 Ok
ARCESS 671.9 306.1 Ok

1989 MAR 30 BER 145112.3 72.500N 8.450E 0 3.1 BER 0.0 2.3 MlW
DIST AZIM Comments....................
TRO 495.3 315.0 Ok
LOF 522.9 341.0 Ok (3C)
ARCESS 698.9 306.0 Ok

1989 APR 09 BKH 44548.8 67.614N 33.860E 0 2.7 HEL N 2.5 MlW
DIST AZIM Comments....................
KTK 464.5 104.6 Ok, Rg phase present

1989 APR 13 BER 234521.7 70.040N 9.515E 0 3.1CBER 0.0 2.2 MlW
DIST AZIM Comments....................
TRO 364.7 281.5 No P-arrival

1989 APR 16 BER 41113.4 66.631N 5.865E 13 3.1CBER 2.9LBER 2.4 MlW
DIST AZIM Comments....................
LOF 368.7 246.6 Ok, short Lg-window
KTK 775.6 258.3 Ok, short Lg-window

1989 APR 16 HEL 63443.6 67.58 N 33.68 E 10 4.1 HEL 3.8 MlW
DIST AZIM Comments....................
KTK 459.[illegible] 105.[illegible] Ok
LOF 846.7 84.6 Ok (3C)

1989 APR 22 BER 180310.7 67.380N 33.893E 15 3.9CBER 0.0 N 3.0 MlW
DIST AZIM Comments....................
KTK 477.[illegible] 107.[illegible] Ok
TRO 659.6 105.2 Ok
MOR 846.9 72.7 Ok
LOF 861.0 86.1 Ok, noisy
NSS 1040.[illegible] 62.5 Ok, noisy

1989 [illegible] 11 [illegible] [illegible] 3.3 [illegible] 2.5 Ml[illegible]
DIST AZIM Comments....................
LOF 186.3 184.6 Ok (3C)
NSS 221.[illegible] 14.1 Ok
TRO 428.5 216.8 Ok
MOL 509.4 29.5 Ok
KTK 511.9 240.9 Ok

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1989 MAY 18  BER  33640.6 65.938N   8.039E  16 3.0CBER 0.0            2.4 MLW
        DIST   AZIM                              Comments....................
NSS     241.5  312.3                             Ok
MOR     306.2  266.8                             Ok
MOL     376.2    3.4                             Ok

1989 MAY 19  BER  61658.9 68.539N  11.107E  15 3.1CBER 0.0            2.5 MLW
        DIST   AZIM                              Comments....................
MOR     300.8  330.2                             Ok
TRO     334.5  252.3                             Ok
NSS     448.6  355.5                             Ok
KTK     492.3  269.5                             Ok
MOL     685.3   12.3                             Ok

1989 MAY 19  BKH 111939.2 69.431N  31.557E   0       3.1 BER       M  2.6 MLW
        DIST   AZIM                              Comments....................
KTK     332.6   78.0                             Ok
TRO     492.7   86.7                             Ok

1989 MAY 22  HEL 121501.6 63.19 N  21.42 E  10       3.2 HEL          2.5 MLW
        DIST   AZIM                              Comments....................
MOR     464.4  133.9                             Ok
NSS     487.8  103.5                             Ok

1989 MAY 25  BER 172921.8 67.099N  20.433E  28 3.0CBER 0.0         M  2.0 MLW
        DIST   AZIM                              Comments....................
MOR     268.1   66.4                             Ok
TRO     289.3  166.9                             Ok
LOF     315.3  108.2                             Ok (3C)
NSS     480.9   49.7                             Ok
```

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